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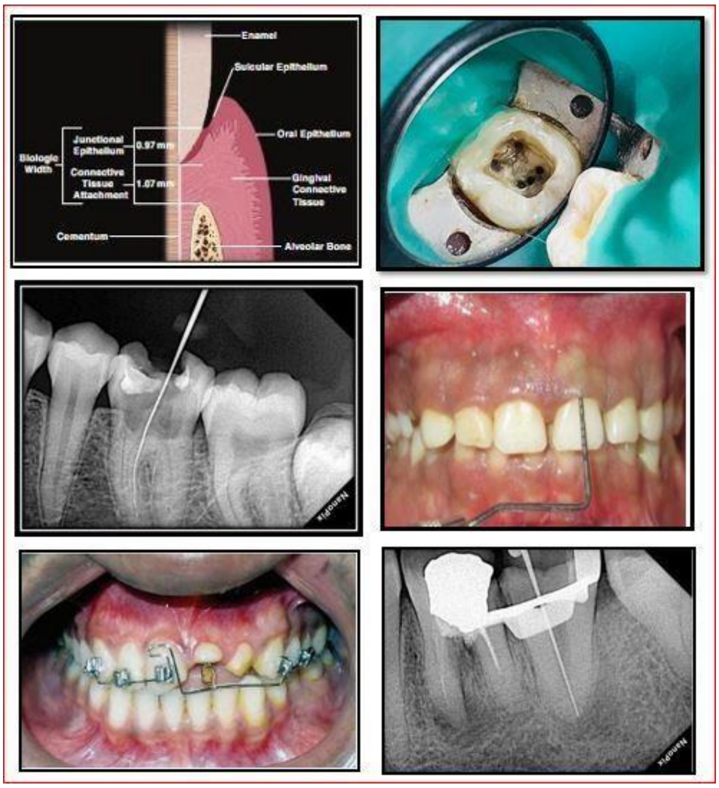

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From the desk of Editor-in-Chief

With immense pleasure I would like to announce that we are publishing the Volume 07 (Issue 01 – Jan - Jun 2025) of MIDSR Journal of Dental Research after the successful publication of six volumes. ***“Everything is possible when you have right people to support”***, I would like to extend my heartfelt thanks to the authors and our management for their constant faith in me and their utter support.

The Volume 07 (Issue 01 – Jan -Jun 2025) has been created with the great efforts of providing the quality manuscripts rather than the quantity, the volume contains case reports and review articles.

I dedicate this issue to all the faculty members of MIDSR Dental College, Latur who immediately responded to the call for manuscripts and submitted their valuable work to the journal.

Dr.Suresh K. Kangane,
Principal,
MIDSR Dental College, Latur.

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Maxillary molar with two palatal canal: Case Report

Dr Ramchandra Kabir[1], Dr Rutuja Kalantri[2], Dr Amol Badgire[3] , Dr Anita Kale[4], Dr Praveen Dhore[5], Dr Ajit Shinde[6]
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Abstract:
Endodontic treatment of maxillary molars with aberrant root canal morphology can present significant diagnostic and technical challenges. Unusual canal configurations in multirooted teeth, such as the presence of additional canals, lateral canals, or apical deltas, are relatively common and require careful assessment for successful treatment outcomes. This case report describes the endodontic management of a maxillary first molar exhibiting an uncommon morphological variation in the palatal root. Specifically, the palatal root contained two canals that appeared to merge in the apical third. The case highlights the importance of recognizing and addressing anatomical variations to ensure effective endodontic therapy.

Keywords: Maxillary first molar, Dental anatomy, Anatomical variations,Root canal

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INTRODUCTION:

Successful root canal therapy depends on the thorough treatment of the entire root canal system. Therefore, a comprehensive understanding of dental anatomy and its possible variations is essential for clinicians.[1]

Several reports in the literature have documented variations in the number of palatal roots and canals in maxillary first molars. These include cases with a single palatal root containing two canals, as well as cases with two distinct palatal roots, each housing its own canal.[2]

Thews.et.al (1997)3, in his description of the lingual root of the maxillary first molar, noted that "in rare examples, this root bifurcates." Similarly, Wheeler emphasized the importance of reviewing dental anatomy from a macroscopic diagnostic perspective and considering the potential variations in root and pulp cavity morphology during endodontic treatment. While the mesiobuccal root often presents with variability in canal configuration, macroscopic variations are less commonly seen in the lingual or distobuccal roots.[3]

The prevalence of additional canals in the palatal root of maxillary molars is estimated between 2% and 5.1%. Christie et.al.(1991)[4] speculated that maxillary molars with two palatal roots may be encountered once every three years in a busy endodontic practice. Stephen documented a case where two palatal canals converged in the apical third. While such occurrences are uncommon, recognizing and treating these anatomical variations is critical to the success of endodontic therapy [5]

Undetected extra canals can lead to treatment failure if not properly identified, cleaned, and obturated.[6]

Anatomical variations can occur in maxillary permanent molars. Christie et al.(1991)[4] reported 16 cases of maxillary molar with two palatal roots and classified them into three types –

Type 1 – Buccal roots are often cow-horn shaped and less divergent. It has two widely divergent palatal roots, often long and tortuous.
Type 2 – Roots are shorter run parallel and have blunt root apices.
Type 3 – Root morphology is constricted with mesiobuccal, mesiopalatal, distopalatal canal engaged in one web of root dentin. The distobuccal root seems to stand alone and may diverge to distobuccal.

This clinical case report presents a maxillary first molar with two palatal canals that appeared to converge in the apical third, emphasizing the importance of recognizing anatomical anomalies during root canal treatment.

CASE REPORT

A 20-year-old male patient reported to the department of Conservative Dentistry and Endodontics with the chief complaint of pain in the right upper back region of the mouth since 15 days. Medical history was non-contributory. The clinical diagnosis was Acute Irreversible Pulpitis.

A pretreatment radiograph was taken (Fig. 1). Local anesthesia was administered. After placing a rubber dam, a conventional access opening was performed show in (Fig 2) . After removing tissues located in the pulp chamber, two orifices were observed in the palatal root. K-file was inserted into the orifices and radiograph was taken which revealed two canals in the palatal root which join at the apical third (Fig. 3). Working length was determined using apex locator (Root ZX, J. Morita, USA).

Root canal was prepared using crown down technique with rotary NeoEndo file system and then mesiobuccal canal and distobuccal canal were enlarged till 25.04% and two palatal canal were enlarged till 25.06% The canals were irrigated with 1% sodium hypochlorite solution, flushed with sterile saline solution and completely dried with absorbent paper points. Periapical radiograph showing Master cone selection (Fig 4) The canals were obturated using standardized gutta-percha points and Bioceramic root canal sealer and tooth was restored with a composite filling (Fig 5).

Fig. 1: Preoperative periapical radiograph

Fig. 2: Access opening showing mesiobuccal canal, distobuccal canal and two palatal canal

Fig. 3: Periapical radiograph showing working length

Fig. 4: Periapical radiograph showing Master cone selection

Fig. 5: Periapical radiograph showing obturation and post obturation restoration

DISCUSSION

In retrospect, the indistinct appearance of the palatal root on the preoperative radiograph should have raised suspicion regarding the possibility of a second canal. Furthermore, the initial working length radiograph showed the file within the palatal root to be off-centered , A finding that should prompt further investigation. Slowey et.al.(1974)[7] emphasized the importance of exploring anatomical anomalies when such radiographic indicators are present. In this case, the second palatal canal was eventually located with the help of a serendipitous radiographic finding that clearly revealed a two-canal system. This case highlights the potential for misdiagnosis when anatomical variations are not anticipated. The initial assumption that the tooth contained only one palatal canal underscores the importance of remaining vigilant. Clinicians must be prepared to reassess and adapt their approach when unexpected morphology is encountered during treatment.[7]

CONCLUSION

The root canal anatomy of each tooth in the human dentition exhibits certain common characteristics, along with numerous anatomical variations that can serve as a roadmap for successful endodontic treatment. Awareness of these variations is crucial from both diagnostic and therapeutic perspectives. Therefore, it is essential to emphasize the importance of identifying unusual morphologies and additional root canals to ensure a successful endodontic outcome.

CLINICAL SIGNIFICANCE

Anatomical variations can occur in all teeth, and recognizing these differences is essential for the success of endodontic therapy. In particular, accurate identification and thorough treatment of all root canals are critical, as failure to locate or properly manage any canal may lead to treatment failure[8]. A comprehensive clinical and radiographic examination, combined with in-depth knowledge of tooth morphology, is therefore crucial to achieving successful endodontic outcomes[9]

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Dens Invaginatus with Radicular Cyst: A Case Report

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Abstract:

Dens invaginatus is a developmental defect characterized by the inward folding of a segment of the crown and/or root that occurs within the enamel organ during the process of odontogenesis. This invagination can manifest as a minor depression on the crown (coronal type) or as a more extensive anomaly that encompasses a significant portion of both the crown and root (radicular type), occasionally leading to the formation of an additional apical foramen. While a clinical assessment may identify a pronounced fissure or pit on the surface of an anterior tooth, imaging techniques provide a more accurate means of determining the severity of the invagination. This case presentation aims to document an unusual instance of a radicular cyst associated with dens invaginatus.

Keywords- Dens invaginatus, Radicular cyst, enucleation, apicectomy.

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INTRODUCTION:

Dens invaginatus is an uncommon developmental aberration characterized by an astonishingly diverse morphological spectrum. Many hypothesis has been given and one of the widely accepted theory is that It is a result of invagination of the crown and/or the root surface before mineralization happens.(1)

Dens invaginatus can manifest itself in both primary and permanent dentitions, with an estimated prevalence ranging from 1.7% to 10%. The condition exhibits a pronounced male predilection, with an observed male-to-female ratio of 3:1. we (2) Moreover, maxillary lateral incisors emerge as the most frequently affected teeth, followed in decreasing order of incidence by permanent central incisors, canines, and molars.(3)

This anomaly is often associated with a constellation of other dental irregularities, including microdontia, gemination, supernumerary teeth, dentinogenesis imperfecta, further emphasizing its complex developmental nature making it susceptible for pupal pathology. (4,5)

Radicular/Periapical cyst is a pathology of jaw involving tooth classified as Odontogenic cyst by the WHO (6) has their etiology associated with necrotic pulp and has most prevalence as a cystic lesion of jaw (7) which can also involve healthy tooth in its cystic lesion leading to further damage at wide extent if go unnoticed (8)

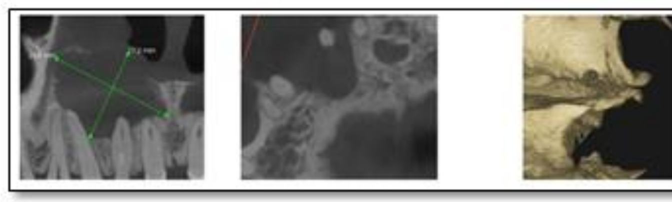
Radicular/Periapical cyst which is commonly associated with carious tooth leading to pulp necrosis can also be associated with non carious dens-invaginetous as its structural anomalies make it susceptible for trauma and constant irritation from local environment further leading to formation of cystic lesion.

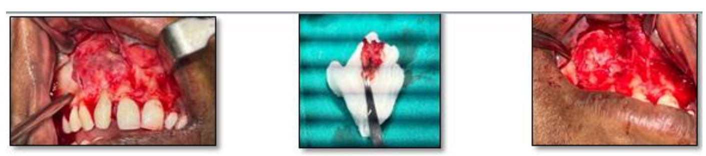
The purpose of this case report is to discuss in detail the association of periapical cyst with dens-invaginatus and its management by using combination of surgical and non surgical method.

CASE REPORT:

31 year old female patient reported in the dept. of Oral and Maxillofacial Surgery, MIDSR, Latur with chief complaint of swelling over upper lip on right side since 3-4 months. The patient's medical history was non-significant. Extra-oral examination showed diffuse swelling of approx 1.5X1.5cm present over upper lip extending from philtrum to nasolabial fold on right side leading to obliteration of nasolabial fold on same side. Intra-orally, a swelling of approx 1X1 cm, roughly oval present over upper labial vestibule with respect to 11, 12, 13 region extending from labial frenulum to distal to 13 and from mucogingival junction to labial mucosa with respect to 11 12 13. On palpation it was firm in consistency. Tender on palpation. The teeth were free of caries and discoloration. However, it was noted that 12 was microdontic and peg-shaped. Panoramic radiograph revealed the presence of a periapical radiolucency surrounded by a sclerotic border in relation to 12 extending up to 14. 12 showed the presence of a wide pulp chamber with radiopaque invagination from a lingual pit towards the root apex crossing the cement-enamel junction.

This invagination was approximately circular with a central core of radiolucency, which was consistent with the diagnosis of a dens invaginatus. After obtaining informed consent about treatment, treatment cost and consent for photography, treatment planned and proceeded for the case was to do endodontic treatment with 11 12 13 followed by enucleation of cystic lesion under general anesthesia along with an apicetomy with 11 12 13.





During enucleation it was observed that 12 has minimal bone support and was necessary to extract to remove sinus lining. Therefore, extraction of 12 was done. The enucleated cyst upon histopathological examination was diagnosed as periapical cyst.

DISCUSSION

Development of an invaginated tooth has been explained based on a number of hypotheses. The earliest hypothesis attributed the malformation to the incomplete fusion of two tooth germs or to the attempted division of a single tooth germ (Bruszt et al) and the most recent hypothesis proposes dental invagination as a-consequence of the degeneration of the dental lamina which can lead to fusion, gemination or agenesia. Oehlers further classified the dens invaginatus into three forms:

- **Type I:** An enamel-lined minor form that occurs within the confines of the crown without extending beyond the amelocemental junction.
- **Type II:** An enamel-lined form invading the root but remains as a blind sac. May or may not have communication with the dental pulp.
- **Type III:** A form that penetrates through the root, perforates apical area showing a "second foramen" in the apical or in the periodontal area with no immediate communication with the pulp. The enamel may completely line the invagination, but frequently cementum can be found lining the invagination

CONCLUSION

Dens invagination frequently left unnoticed and allows the entry of irritants into an area, which is separated from the pulpal tissue by only a thin layer of the enamel. Even sometimes, the enamel lining may be incomplete or channels may exist connecting the invagination and the pulp making it difficult for the instrumentation.

Such anatomical variation may lead to pathology like radicular cyst if gets infected. Therefore if such anomaly is detected regular radiological follow up and/or prophylactic endodontic treatment should be performed to prevent further complications.

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Case Report

Precision Replication of Occlusal Anatomy Using the Stamp Technique: A Case Report

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Abstract:

The stamp technique is a minimally invasive and highly precise method used in restorative dentistry to replicate the natural occlusal anatomy of posterior teeth. This case report describes the use of the stamp technique in a 23-year-old female patient, who presented with pit and fissure caries in tooth 46. Clinical and radiographic evaluation revealed an intact occlusal surface with early carious involvement, making the case ideal for the stamp approach. A flowable composite was used to create a stamp of the occlusal surface prior to cavity preparation. After standard etching and bonding protocols, the cavity was restored with composite resin using the preformed stamp to replicate the original anatomy. The technique significantly reduced the need for occlusal adjustments and polishing, yielding a highly aesthetic and functional result. This case highlights the efficiency, accuracy, and patient centred advantages of the stamp technique in conservative restorative dentistry.

Keywords: Stamp technique, Minimally invasive restoration, Direct composite restoration

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INTRODUCTION:

In recent years, the demand for aesthetic and minimally invasive dental treatments has led to the widespread use of composite resin restorations in posterior teeth. While composite materials offer advantages such as superior aesthetics and conservation of tooth structure, challenges remain in replicating precise occlusal anatomy, especially in Class I cavities. Traditional free-hand sculpting techniques are time-consuming and technique-sensitive, often requiring extensive finishing and polishing to achieve functional harmony.

The stamp technique, introduced to address these limitations, it is a restorative method that effectively combines aesthetics and function by precisely replicating the tooth's original occlusal anatomy prior to cavity preparation. Dr. Waseem Riaz, a dental practitioner based in London, introduced and advocated this technique for achieving precise occlusal topography in direct composite resin restorations1–3.

The technique is ideal for cases involving shallow to moderate occlusal caries, where the occlusal anatomy remains largely intact However, in cases with extensive tooth structure loss such as large MOD (mesial-occlusal-distal) cavities or when the occlusal surface is severely decayed, where the cavity margins are subgingival the technique becomes less viable4.
This case report illustrates the application of the stamp technique in a 23-year-old female patient with pit and fissure caries in the mandibular left second molar(37), demonstrating its effectiveness in preserving natural tooth anatomy while delivering aesthetically pleasing and functionally sound results.

Case Presentation
A 23-year-old female patient, reported to the Department of Conservative Dentistry and Endodontics with a chief complaint of black discoloration and occasional food lodgement in her lower left back tooth region.
Her past medical and dental history were non-contributory. On intraoral clinical examination, tooth number mandibular left second molar (37) exhibited pit and fissure caries, with the marginal ridges intact and no visible cavitation. The occlusal surface showed anatomical integrity, making it an ideal case for the stamp technique.

Fig 1: Preoperative Photograph

To assess pulpal status and the extent of carious involvement, an intraoral periapical radiograph was taken, which revealed superficial occlusal radiolucency with no periapical changes.

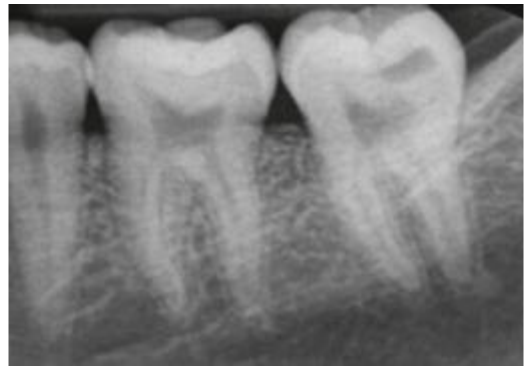


Fig 2: Preoperative radiograph

Rubber dam isolation was achieved to provide a clean and moisture-free operating field. A thin layer of separating medium was applied to the occlusal surface of tooth 37 using a microbrush. This was done to ensure that the stamp could be removed easily after fabrication.

Fig 3: Application of a single coat of petroleum jelly with applicator tip

To create the occlusal stamp, a layer of flowable composite (Tetric N-Flow, Ivoclar Vivadent, Schaan, Liechtenstein) was applied over the intact occlusal anatomy of tooth 37. A trimmed microbrush tip was inserted into the unset composite to act as a handle. This setup was then light-cured to form a rigid stamp that preserved the preoperative occlusal morphology.

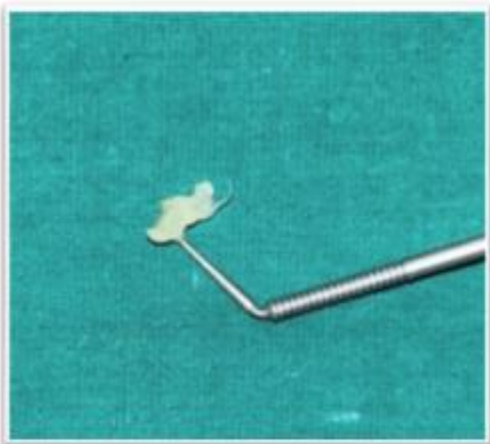
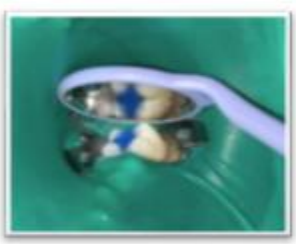


Fig 4: Occlusal stamp made using microbrush stamp technique

Following stamp fabrication, standard cavity preparation was performed. Carious tissue was removed, and a conservative Class I cavity design was established to provide proper retention and resistance form. Care was taken to preserve as much natural tooth structure as possible.

(a)



(b)

(c)

Fig 5: (a) caries excavation/ cavity preparation (b)enamel etching with 37% ortho phosphoric acid(c)Application of bonding agent

The prepared cavity surfaces were then etched with 37% orthophosphoric acid (Prime Dental, Ahmedabad, India) for 30 seconds to create microretentive areas for bonding. The etchant was thoroughly rinsed off, and the surface was gently air-dried using a three-way syringe. A universal bonding agent (Single Bond Universal, 3M ESPE, St. Paul, MN) was then applied to the etched surfaces according to the manufacturer's instructions and light-cured for 20 seconds.

(a)

(b)

(c)

Fig 6: (a)Teflon applied covering the occlusal surface(b)Microbrush stamp pressed over the cling film(c)Final restoration

Composite restoration was carried out incrementally using Spectrum composite (Dentsply Sirona). The cavity was filled to a level approximately 1 mm below the original occlusal surface and light-cured. For the final increment, a thin layer of composite was placed, and a strip of Teflon tape was laid over it to prevent the composite from sticking to the stamp. The preformed occlusal stamp was carefully positioned over the Teflon tape and gently pressed to transfer the original occlusal anatomy. Once the stamp was removed, the final layer of composite was light-cured to complete the restoration.

Minimal finishing and polishing were required due to the accuracy of the occlusal reproduction. Final polishing was performed using a polishing paper disc (Shofu Super-Snap Mini Kit, Kyoto, Japan) to achieve a smooth and lustrous surface. Postoperative instructions were given to the patient, emphasizing the importance of maintaining oral hygiene and avoiding hard or sticky foods for 24 hours. A follow-up visit was scheduled after 3 months to assess the restoration's function and integrity.

DISCUSSION

The primary objective of a dental restoration is to restore the shape, function, phonetics, and aesthetics of a damaged tooth. Restorations are broadly classified into two types: Direct and Indirect. Direct restorations are placed directly within the patient's oral cavity and are generally suitable for small to moderate cavities. They offer advantages such as minimal tooth preparation and lower cost. However, they require a high degree of clinical skill. In contrast, indirect restorations are fabricated outside the oral cavity either in a dental laboratory or with CAD/CAM technology and are later cemented into the mouth5. The choice between direct and indirect restorations depends on factors such as the extent of the tooth damage, aesthetic demands, and clinical feasibility.

The stamp technique is an innovative and conservative approach that addresses one of the major challenges in direct posterior composite restorations: replicating the tooth's natural occlusal anatomy. In conventional freehand techniques, achieving ideal cusp-fossa relationships and occlusal balance often requires significant time for sculpting and post-curing adjustments6. In contrast, the stamp technique provides a preoperative impression of the original anatomy, significantly reducing finishing time and improving accuracy.

Merits of the Stamp Technique

- **Faster procedure:** Saves time by eliminating the need to manually recreate the occlusal anatomy.
- **Reduced material consumption:** Requires less restorative material due to precise anatomical replication.
- **Decreased chairside time:** Minimizes occlusal adjustments, conserving time and articulating paper.
- **High accuracy:** Accurately replicates the original occlusal anatomy, ensuring better anatomical fidelity.

In this case, tooth 37 presented with pit and fissure caries without significant structural breakdown, making it an ideal candidate for the stamp technique. The intact occlusal surface allowed for the fabrication of a detailed and accurate stamp using flowable composite. During the final restoration, this stamp ensured precise anatomical reproduction, enhancing functional efficiency and aesthetic integration.

Other cost-effective materials could be considered as follows:

- Pit and fissure sealants
- Poly methyl methaacrylate [clear]
- Pattern resin
- Gingival dam material
- Vacuum formed template.
- Bite registration material

Moreover, the technique minimized material wastage and operator fatigue, as the need for multiple occlusal adjustments and extensive polishing was eliminated. Literature supports that this method not only reduces chair time but also enhances marginal adaptation and minimizes polymerization shrinkage, as pressure applied by the stamp helps in compacting the composite and reducing air entrapment7–9.

However, as with any clinical technique, it has limitations. The stamp technique is only applicable in cases where the occlusal surface is intact or minimally affected. If the occlusal anatomy is significantly destroyed or altered, the use of this technique becomes unfeasible. Additionally, fabrication of the stamp must be carried out with precision to avoid distortion during handling or polymerization.

Overall, this case demonstrates that with proper case selection, the stamp technique offers a highly efficient, minimally invasive, and aesthetically superior alternative to conventional composite restoration methods.

CONCLUSION

The stamp technique is a reliable and effective method for restoring posterior teeth when the original occlusal surface is intact. It allows for the reproduction of natural occlusal anatomy with high precision while reducing operative time, minimizing finishing and polishing efforts, and enhancing patient satisfaction. In the present case involving tooth 37 of a 23-year-old female patient, the technique proved to be highly successful in achieving both functional and esthetic outcomes. With appropriate case selection and careful handling, the stamp technique can significantly enhance the quality and efficiency of restorative procedures in daily clinical practice.

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Clinical Insights on Mesiodens: A Case Series

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Abstract:

Supernumerary teeth, also known as hyperdontia, refer to the presence of additional teeth beyond the normal dental count in the arch. The prevalence of supernumerary teeth in the anterior region is 2.2%, with mesiodens accounting for 78.4% of these cases. Mesiodens, the most common type of supernumerary teeth, can cause several complications, including spacing, crowding, eruption issues, and esthetic concerns. These anomalies are particularly significant during the primary and early mixed dentition stages, as they can lead to various dental problems such as speech difficulties, resorption of adjacent tooth roots, delayed eruption of permanent incisors, and the potential development of dentigerous cysts. Early identification and management of mesiodens are crucial to avoid further complications in permanent dentition. The current paper focuses on seven cases of mesiodens identified during the primary, mixed and permanent dentition phase, along with their effective management strategies.

Keywords: Mesiodens, Supernumerary tooth, Pediatric dentistry, Case reports

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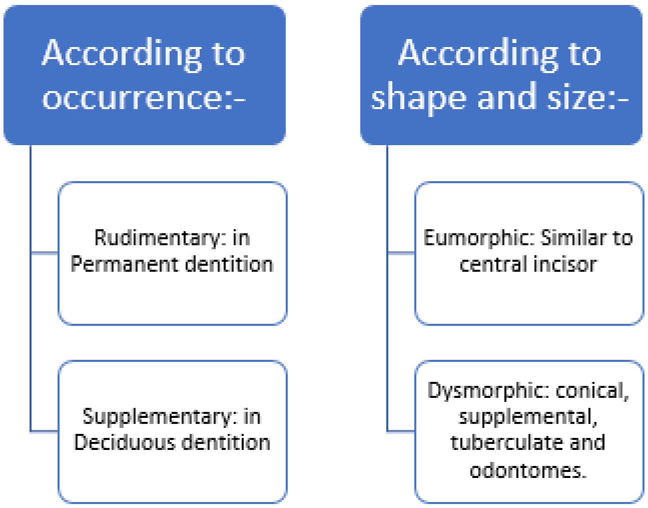
INTRODUCTION:

Supernumerary teeth are additional teeth that develop in the mouth and can affect the eruption and alignment of normal teeth.1 Mesiodens are the most common type of supernumerary teeth, typically found in the maxillary anterior region between the central incisors. The prevalence of supernumerary teeth is 0.15–1% in permanent dentition and 0.3–0.6% in the primary dentition with predilection of 2:1 for male sex.2 These teeth are often identified during routine dental examinations or as a result of complications such as delayed eruption, diastema, displacement of adjacent teeth, or root resorption.3 While mesiodens may remain asymptomatic, their presence near critical anatomical structures such as the nasal floor can pose diagnostic and surgical challenges. It can affect both maxilla and mandible; however, its occurrence in the mandible is rare.4 The most common type of supernumerary tooth as indicated by Alberti et al is mesiodens. Mesiodens may occur as single, multiple, unilateral or bilateral.5 The exact etiology of mesiodens tooth is not clearly known, though various theories have been suggested, including dichotomy of the tooth bud, hyperactivity of the dental lamina and combination of genetic-environmental factors. Single supernumerary teeth may be seen in association with conditions like cleft lip and/or palate, Downs syndromes, Cleidocranial dysplasia, etc.6 In some syndromes, mesiodens may present as a part of the symptoms; however, this condition might be seen in normal individuals. It seems that positive family history is one of the predisposing factors.5

Classification of mesiodens. 7



Supernumerary teeth are typically extracted by 5-10 years of age to prevent complications in developing dentition and minimize need for orthodontic interventions, which are lengthy and bothersome usually. The mesiodens, typically located beside the maxillary central incisors, are the most prevalent type of supernumerary teeth. The treatment of choice for mesiodens is extraction as the first line of treatment. If it is impacted, a tran-alveolar dis-impaction through palatal approach is most preferred one.3

CASE 1:

A 12-year-old female patient reported to the Department of Paediatric and Preventive Dentistry, MIDSR, Latur with a chief complaint of speech problem. Her secondary complaints were centrally placed tooth and aesthetic problems concerns.

On the intraoral examination, it revealed the presence of a supernumerary tooth, which was diagnosed as a mesiodens. It was positioned between to central incisors (11-21), on the labial aspect. It was placed more mesially in first quadrant causing slight midline shift. Presence of mesiodens more mesially in first quadrant resulted in buccal eruption of canine (13) as well as distal rotation of central incisor (11). Presence of mesiodens did not cause any discrepancies in occlusion, it showed class I molar relation bilaterally due to placement of mesiodens more nasally. Figure 1.1 and 1.2 shows intraoral clinical photograph of mesiodens.

On radiographic examination it revealed that presence of conical shaped mesiodens placed near nasal septum and parallel to two central incisors pushing 11 distally. Figure 1.3 intraoral periapical radiograph.

After clinical and radiographic examination, the treatment was planned as extraction of mesiodens under local anaesthesia. Figure 3 shows extracted mesiodens.

Fig 1.1 Intraoral frontal view

Fig 1.2 Intraoral clinical photograph of mesiodens

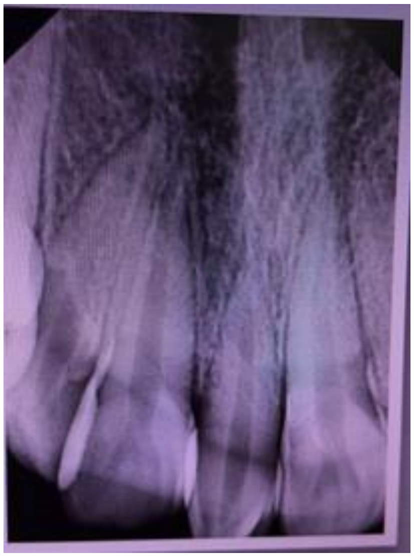


Fig 1.3 Intraoral periapical radiograph

CASE 2:

A 12-year-old female patient came to Department of Pediatric and preventive dentistry with a chief complaint of an extra tooth in upper front teeth region. The patient complained of irritation caused by this tooth. There was no associated trauma or pain and no sign of any syndrome were evident.

Intraoral examination revealed the presence of mesiodens which is conical in shape between teeth 11 and 21 (Fig. 2.1). A subsequent IOPA radiograph was taken to confirm the presence of mesiodens. Radiographically tooth appear as sharp conical in shape along with tapered root (Figure 2.2). Treatment was planned and executed to extract the mesiodens. Wound healing progressed normally and patient presented with no postoperative complications. (Fig 2.3)

Fig 2.1 Pre-op Intraoral Periapical radiograph

Fig 2.2 Pre-op Intraoral clinical photograph

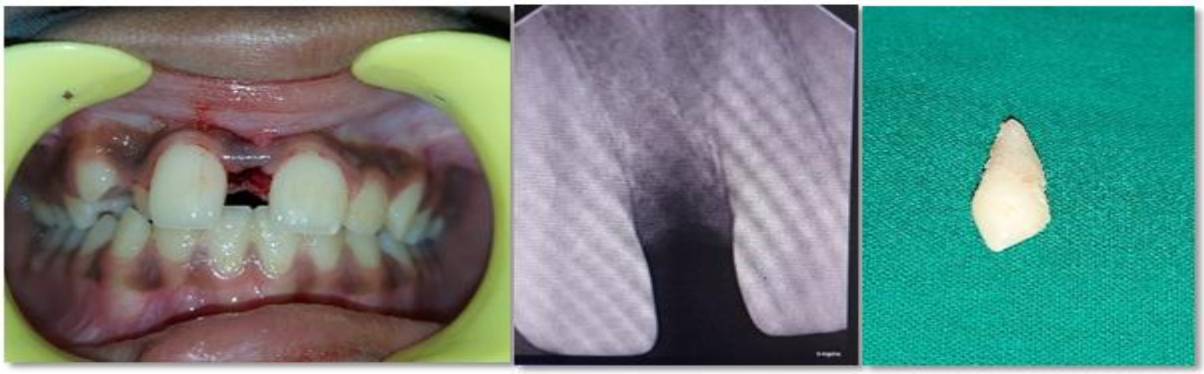


Fig 2.3 Post-op intraoral clinical photograph, periapical radiograph of mesiodens

CASE 3:

A 13-year-old patient reported to Department of Pediatric and Preventive Dentistry with chief complain of extra tooth in upper front region of jaw.

Patients medical and family history was noncontributory and no sign of any associated syndrome were evident.

Intraoral examination revealed a mesiodens in upper arch (Figure 3.1) Intraoral photographs are shown in Figure 3.2. the mesiodens had a conical long root. The treatment focused on improving patient's speech and aesthetics, which led to extraction of embedded supernumerary tooth. Figure 3.2 shows extraction socket and extracted mesiodens.

Fig 3.1 Intraoral clinical photographs of mesiod

Fig 3.2 Extraction socket and extracted

CASE 4:

A 13-year-old patient reported to Department of Pediatric and Preventive Dentistry with chief complaint of speech impairment and sensitivity in upper front teeth region of jaw. There was no relevant medical or family history.

Intraoral examination revealed permanent dentition with the presence of mesiodens deviating 21 labially (Fig 4.1). Radiographic examination showed presence of conical supernumerary wedged between upper two central incisors. Treatment involved extraction with mesiodens (Fig 4.2 and 4.3)

Fig 4.1 Intraoral clinical photographs of

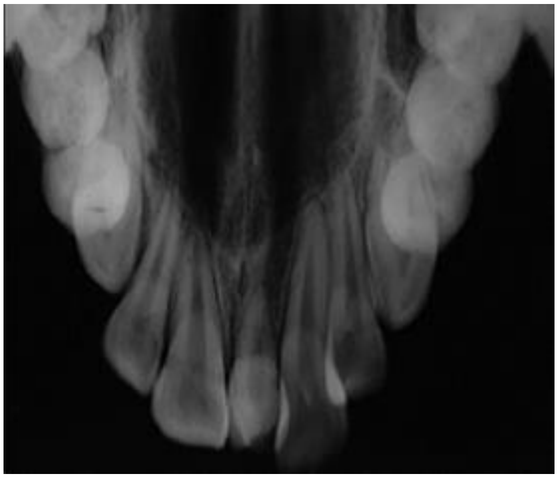


Fig 4.2 Radiograph of mesiodens

Fig 4.3 Extracted mesiodens

CASE 5:

A 9-year-old male patient presented to the Department of Paediatric and Preventive Dentistry with a chief complaint of pain on mastication and an extra tooth in the upper front tooth region of the jaw. The patient provided no history of trauma. The patient's medical history and family history are non-contributory.

Intraoral clinical examination revealed the presence of a supernumerary tooth, which was diagnosed as mesiodens and positioned between maxillary right and left central incisors on the palatal aspect. Figure 5.1 depicts an intraoral clinical photograph of the maxillary anterior region, showing mesiodens.

An intraoral periapical radiograph was recommended to locate the exact position of mesiodens in the maxillary anterior region. Figure 5.2 shows an intraoral periapical radiograph of the maxillary anterior region.

Based on all the clinical findings and examinations, an extraction of mesiodens was planned. Figure 5.3 shows extracted mesiodens.

Fig 5.1 Clinical photograph of maxillary anterior region, showing mesiodens

Fig 5.2 Intraoral periapical radiograph of the maxillary anterior region

Fig 5.3 Extracted mesiodens

CASE 6:

A 8-year-old male patient came to Department of Pediatric and Preventive Dentistry with a chief complaint of persistent, dull, throbbing pain localized to right temporomandibular joint and radiating behind right ear. Patient denied any associated symptoms such as swelling, fever or discharge. He reported that mastication of hard food exacerbated the pain.

An intraoral clinical examination revealed the presence of a supernumerary tooth, which was diagnosed as a mesiodens, and it was positioned between upper central incisors on the palatal aspect. Due to the presence of the mesiodens, there was premature contact between teeth, which results in an imbalance occlusion. (Fig 6.1)

An intraoral occlusal radiograph was recommended to locate the exact position of the mesiodens in the maxillary anterior region and diagnosis of supernumerary teeth was made as mesiodens (Fig 6.2). Based on all the clinical findings and examinations, an extraction of mesiodens was planned. There was no postoperative complications present after extraction.(Fig 6.3 and 6.4)

Fig 6.1 Pre-op Intraoral clinical photograph

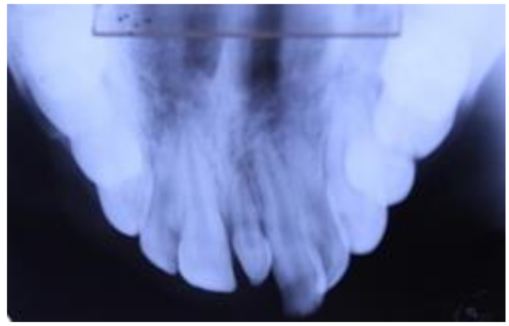


Fig 6.2 Pre-op Intraoral Periapical radiograph

Fig 6.3 Extracted mesiodens

Fig 6.4 Post-op intraoral clinical photograph

CASE 7:

A 9-year-old patient reported to Department of Pediatric and Preventive Dentistry with chief complain of extra teeth in upper front region of jaw. Patients medical and family history was noncontributory.

Intraoral examination revealed a mesiodens in upper arch, intraoral photographs are shown in Figure 7.1. the mesiodens had a conical long root. The treatment was focused on improving patient's speech and aesthetics. Complete extraction of embedded supernumerary tooth was done under local anesthesia. Figure 7.2 show extracted mesiodens.

Fig 7.1 Pre-op Intraoral

Fig 7.2 Extracted mesiodens

DISCUSSION

Impacted mesiodens can lead to significant complications, such as displacement of adjacent teeth, midline diastema, delayed eruption of permanent teeth, and root resorption. The literature emphasizes the importance of timely intervention, as seen in similar cases where delayed management exacerbated orthodontic complications. Surgical extraction remains the treatment of choice, particularly when the mesiodens interferes with normal occlusion or causes aesthetic concerns.

Detection of these supernumerary teeth is best achieved by clinical and radiographic examination. An anterior occlusal radiograph is useful in locating a mesiodens. In some of our cases like case 1,2,3,4,6 IOPA radiograph revelled presence of mesiodens in the midline of maxillary arch which was embedded in parallel direction. Intraorally anterior presence of embedded mesiodens gave unesthetic appearance to the patient and also would have interfered with the eruption of permanent teeth, hence it was extracted. While in two cases like case 5 and 7 it was located on palatal aspect. The presence of palatally placed mesiodens results in disturbance in occlusion causing TMJ pain. Thus the treatment was aimed at addressing the patient's need for alleviate TMJ pain as well as improved speech, mastication and aesthetics.
Most of the time, supernumerary teeth are asymptomatic but as always problems may appear that include periodontitis, dilacerations, dentigerous cyst formation, root resorption of adjacent teeth, occlusive disturbance and no aesthetic appearance.9
In each case we took 14-day follow-up, it was observed that the patient had no pain and had no more difficulty with mastication as well as in the closure of the mouth. After the follow up when patients' concerns were eliminated and satisfactory healing seen with extraction socket, patients were referred to department of orthodontics for midline diastema and malocclusion.

This case underscores the need for a multidisciplinary approach, combining radiographic evaluation and clinical expertise, to ensure accurate diagnosis and successful treatment. In this instance, the mesiodens was surgically extracted without complications, and the patient will be monitored for orthodontic correction to address any residual malocclusion. Previous studies have highlighted the importance of follow-up care to ensure optimal alignment of the dentition and to prevent recurrence of functional or aesthetic issues.

CONCLUSION

Whenever supernumerary teeth are diagnosed, single or multiple, treatment options should be reviewed carefully. Therapy of supernumerary/supplementary teeth is usually the extraction as seen in all cases. But also, an excess tooth in the dentition can be left as a replacement tooth in some cases, due to a previously lost permanent tooth from the dentition, if its biological value and potential is sufficient to complete the dentition both functionally and aesthetically.

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Review Article

Basal Implant Rehabilitation of Anterior Maxillary Ridge Defect Following Trauma: A Case Report

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Abstract:

Restoring aesthetics is a key priority in dental rehabilitation, particularly when managing trauma to the anterior maxilla. Teeth in this region are frequently lost due to avulsion or must be removed because of severe fractures. Reconstructing such cases is complex due to cosmetic expectations and anatomical challenges. Conventional dental implants often require sufficient bone support, and in cases of deficient bone, additional surgical interventions like grafting or sinus augmentation may be necessary. However, these procedures are not always practical. Basal implants provide an alternative, engaging the dense basal bone for stability, allowing immediate placement of prostheses, and minimizing the need for augmentation procedures. This case report highlights the use of a single-piece basal implant to rehabilitate an anterior maxillary ridge defect following trauma, achieving rapid functional and esthetic restoration.

Keywords: Basal implant, Anterior maxilla, Trauma, Immediate loading, Ridge defect, Oral rehabilitation

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INTRODUCTION:

The anterior maxilla plays a critical role in both function and appearance. Trauma in this region not only impairs oral function but also has a profound psychosocial impact, influencing self-confidence and social interactions [1]. The loss of anterior teeth at a young age particularly affects speech articulation, smile dynamics, and social acceptability. The visibility of this region during communication and expression makes its rehabilitation one of the most demanding areas in dentistry.

Trauma is a leading cause of tooth loss in the anterior maxilla, with avulsion, root fractures, and alveolar bone fractures being common sequelae [2]. Children and young adults are especially vulnerable due to road traffic accidents, sports injuries, and falls. Early loss of anterior teeth also disturbs alveolar bone development, often leading to long-term ridge defects [3]. In addition, psychosocial studies have shown that missing anterior teeth are strongly correlated with negative self-perception, social withdrawal, and reduced employability [4].

Over the past few decades, dental implants have revolutionized tooth replacement, offering superior long-term outcomes compared to removable or fixed partial dentures [5]. Osseointegrated implants, as popularized by Brånemark, are regarded as the gold standard for tooth replacement due to their high survival rates and ability to preserve adjacent tooth structure [6]. However, their success largely depends on the quantity and quality of alveolar bone available for implant placement [7]. In trauma cases where bone loss is common, conventional implants often necessitate ridge augmentation, sinus lift, or guided bone regeneration to create adequate bone volume [8].

While effective, these adjunctive procedures present several drawbacks. They are invasive, increase treatment cost and duration, and may cause donor site morbidity when autogenous grafts are used [9]. Moreover, they are contraindicated in patients with systemic conditions such as diabetes, smoking, or poor compliance [10].

Basal implantology offers a distinct advantage in cases where conventional implants are limited by ridge deficiency or the need for augmentation. Unlike traditional systems that rely on crestal alveolar bone, basal implants engage the dense cortical basal bone, which remains relatively unaffected by trauma, resorption, or infection [11]. This provides excellent primary stability even in severely atrophic ridges [12]. Furthermore, their single-piece design with polished surfaces reduces the risk of peri-implantitis and facilitates immediate prosthetic loading, thereby shortening treatment duration and enhancing patient comfort [13].

This paper presents the case of a young male rehabilitated with a basal implant in the anterior maxilla following trauma, highlighting its advantages in immediate esthetic and functional recovery.

CASE PRESENTATION:

A 19-year-old male reported to the Department of Oral and Maxillofacial Surgery with the chief complaint of a missing upper front tooth. The patient had sustained a road traffic accident (RTA) two years earlier, which led to the loss of teeth 11 and 12. He expressed dissatisfaction with his appearance and sought a fixed replacement that could be delivered immediately.

HISTORY:

The patient's medical history was non-contributory, with no significant systemic illness, and he reported being a non-smoker and non-alcoholic. Dental history revealed extraction of the traumatized upper central and lateral incisors at a private clinic following an accident, with no attempt made for prosthetic replacement thereafter. Psychosocially, the patient expressed reduced self-confidence, avoidance of smiling, and difficulty in social interactions, primarily due to the absence of anterior teeth

CLINICAL EXAMINATION:

On extraoral examination, no facial asymmetry was observed, and the patient exhibited normal lip competency. Intraorally, edentulism was noted in relation to 11 and 12, associated with a horizontal ridge defect. The adjacent teeth, 21 and 13, were intact and demonstrated a healthy periodontium, although the edentulous ridge contour appeared deficient in buccolingual width. Soft tissue examination revealed an adequate band of keratinized gingiva with no signs of active pathology.

RADIOGRAPHIC FINDINGS:

Cone-beam computed tomography (CBCT) examination revealed a residual cystic lesion in the region of 11 and 12. The buccolingual ridge width measured approximately 2 mm, which was inadequate for conventional implant placement. However, the palatal cortical bone was found to be intact, providing a suitable site for bicortical engagement.

TREATMENT PLANNING:

Various treatment options were considered for rehabilitation. The first option was placement of a conventional implant following ridge augmentation with an autogenous chin graft; however, this was declined due to the longer treatment duration and the patient's preference for an immediate esthetic solution. The second option, a fixed partial denture, was also refused by the patient as it required preparation of the adjacent natural teeth. Consequently, the third option, placement of a basal implant with immediate loading, was selected. This approach was deemed most suitable considering the buccolingual ridge deficiency, its minimally invasive nature, and the advantage of providing an immediate prosthetic outcome.

SURGICAL PROCEDURE:

Under local anesthesia (2% lignocaine with adrenaline 1:80,000), "Following flap elevation, the residual cystic lining was carefully enucleated in toto to ensure complete removal and minimize recurrence risk.

Fig 1: Flap elevation followed by cyst enucleation

The defect was thoroughly debrided, and primary stability of the implant site was confirmed. Subsequently, endosseous implants were placed within the same surgical session, taking advantage of the prepared site and reducing the need for a second intervention. This approach not only shortened the overall treatment duration but also facilitated early functional rehabilitation for the patient. Sequential osteotomy preparation was carried out with careful engagement of both the palatal and nasal cortical plates. A single-piece bicortical screw basal implant measuring 2.7 × 13 mm was placed in relation to 11, achieving satisfactory primary stability. Intraoperatively, the implant angulation was adjusted to facilitate proper prosthetic alignment.

Fig 2: Placement of implants followed by resorbable suture placement

In the prosthetic phase, an impression was recorded immediately following implant placement using addition silicone material to ensure accuracy and dimensional stability. A definitive metal-ceramic crown was fabricated within 72 hours, allowing for immediate functional and esthetic rehabilitation. The crown was cemented using Type I luting glass ionomer cement, providing optimal retention and biocompatibility. Careful occlusal adjustments were performed to eliminate premature contacts and minimize functional stresses, thereby protecting the implant during the critical osseointegration period. The immediate loading protocol not only addressed the patient's esthetic concerns but also contributed to improved psychological well-being and early functional recovery.

Fig 3: Placement of crown

Postoperative follow-up demonstrated favorable outcomes. At one week, healing was uneventful with no reports of pain or implant mobility. At the one-month review, the crown remained in place and the patient expressed satisfaction with the esthetic outcome. By the third month, the implant exhibited excellent stability, with satisfactory gingival adaptation and a natural esthetic appearance. At the six-month follow-up, functional integration was confirmed, with no clinical signs of inflammation or peri-implant complications observed.

DISCUSSION:

Rehabilitation of anterior maxillary ridge defects remains one of the most challenging aspects of implantology, primarily due to the dual concerns of high esthetic demands and compromised bone availability. The present case highlights the clinical applicability of basal implants in overcoming these limitations by providing a minimally invasive, graftless, and immediately loadable solution.

PROSTHETIC ALTERNATIVES:

Several treatment modalities are available for anterior edentulism. Removable partial dentures, while economical, often compromise esthetics, phonetics, and patient comfort [7]. Fixed partial dentures (FPDs) offer better stability but at the expense of sacrificing adjacent healthy teeth and carry a risk of secondary caries and periodontal breakdown [8]. Conventional implants, considered the gold standard when bone availability is adequate, require a minimum ridge width of 5–7 mm and are frequently associated with adjunctive grafting procedures [9].

LIMITATIONS OF CONVENTIONAL IMPLANTOLOGY:

Conventional implant placement is highly dependent on sufficient alveolar bone and often necessitates augmentation techniques such as sinus lift, guided bone regeneration, or block grafts [10] These procedures are associated with increased morbidity, extended healing periods of 3–6 months before prosthetic loading, and higher overall treatment costs.

ADVANTAGES OF BASAL IMPLANTS:

Basal implantology offers several advantages in compromised situations. The engagement of basal cortical bone provides excellent primary stability and resists resorption [12] Immediate loading is achievable, allowing impressions and prosthetic rehabilitation within 72 hours [12]. The flapless approach minimizes surgical trauma, preserves periosteal blood supply, and accelerates healing [13]. Additionally, the polished implant surface reduces biofilm accumulation and lowers the risk of peri-implantitis [12]. Basal implants are particularly indicated in challenging cases such as trauma, atrophic jaws, advanced periodontitis, or failure of conventional implants

LITERATURE SUPPORT:

Ihde [6] described basal implantology as a graftless alternative, eliminating the need for augmentation procedures. A Cochrane review [5] emphasized the invasiveness and unpredictable outcomes associated with bone grafting in conventional implantology. Furthermore, clinical studies have consistently demonstrated survival rates exceeding 95% for basal implants, even in severely resorbed ridges [12]. Kim et al. [13] further highlighted the benefits of flapless placement, including reduced postoperative morbidity.

ESTHETIC CONSIDERATIONS:

The anterior maxilla presents unique esthetic challenges, where implant angulation, gingival contour, crown morphology, and smile line must be carefully managed [4]. In the present case, intraoperative correction of implant angulation ensured harmonious crown placement, while the flapless approach contributed to the preservation of soft tissue architecture, enhancing the final esthetic outcome.

PSYCHOSOCIAL IMPACT:

Beyond functional rehabilitation, the psychosocial aspect plays a pivotal role, particularly in young patients. Immediate esthetic restoration significantly improves self-confidence, social interactions, and psychological well-being. In this case, basal implantology provided a patient-centered solution by delivering rapid esthetic and functional rehabilitation while avoiding the prolonged treatment duration associated with conventional protocols.

CONCLUSION:

Basal implants present a reliable and efficient alternative to conventional implantology, particularly in cases of severe ridge deficiency and post-traumatic defects. By engaging the cortical basal bone, they provide excellent primary stability without the need for augmentation procedures. The advantage of immediate prosthetic loading allows for rapid functional and esthetic recovery, which is especially valuable in young patients with high esthetic expectations.

The present case reinforces the significance of basal implantology as a practical, minimally invasive, and patient-centered approach in modern oral rehabilitation. However, long-term clinical studies with larger sample sizes are warranted to further validate their success rates and establish their role as a mainstream treatment modality.

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Revolutionizing Orthodontics: A Review on Distraction Osteogenesis Techniques and Trends

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Abstract:
Distraction osteogenesis (DO) is a biologically driven technique that enables gradual bone elongation and simultaneous soft tissue adaptation through controlled mechanical tension. Originally introduced in orthopedics, DO has revolutionized craniofacial reconstruction and orthodontics by eliminating the need for grafting procedures in cases of mandibular and maxillary deficiencies. This review highlights the fundamental principles, phases, and classifications of DO, emphasizing its role in correcting congenital and acquired craniofacial deformities. The paper also elaborates on orthodontic considerations, clinical indications, device classifications, complications, and recent advancements including internal distraction systems, 3D planning, and bioengineering approaches such as stem cells and growth factors. While DO offers multiple benefits like minimal relapse, better adaptation of soft tissues, and broader applicability across age groups, it is technique-sensitive and requires meticulous planning and patient compliance. The integration of modern technologies and biologic enhancers promises to refine this technique further, making it a cornerstone of skeletal orthodontic interventions.

Keywords: Distraction Osteogenesis, Craniofacial Deformities, Skeletal Orthodontics, Mandibular Lengthening, Bone Regeneration, Orthognathic Surgery, 3D Planning, Soft Tissue Adaptation, Complications of DO, Pediatric Distraction.

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INTRODUCTION:

Distraction osteogenesis (DO), colloquially known as "callotasis", is an orthopedic surgical method which harnesses the body's natural bone healing process to lengthen hypoplastic or deficient bones.[1] Distraction osteogenesis is used synonymously with "Osteo-distraction", "Trans osseous synthesis" or "bone lengthening".

Distraction Osteogenesis is defined as the creation of de novo bone and adjacent soft tissue after the gradual and controlled displacement of a bone fragment obtained by surgical osteotomy.

Distraction Osteogenesis (DO) involves gradual, controlled displacement of surgically created fractures (subperiosteal osteotomy) by incremental traction (Ilizarov, 1988), resulting in simultaneous expansion of soft tissue and bone volume due to mechanical stretching through the osteotomy site (Ilizarov, 1989).[2]

Distraction Osteogenesis is described as "A biological process of formation of new bone between the surfaces of bone segments sequentially separated by incremental traction" by Samchukov M.L., Cherkashin A.N., and Cope J.B.[3] Another definition was given by Aranson who stated, "Distraction Osteogenesis is defined as a gradual, dynamically induced, intramembranous process of ossification between two active bone surfaces that are temporarily separated by minimal energy techniques”. The term distraction osteogenesis is synonymous with “Trans osseous synthesis” or “Osteo-distraction” or in simpler term, “Bone lengthening”.[4] Among the relatively common anomalies of the craniofacial complex are congenital micrognathia, facial asymmetry, and maxillomandibular hypoplasia.

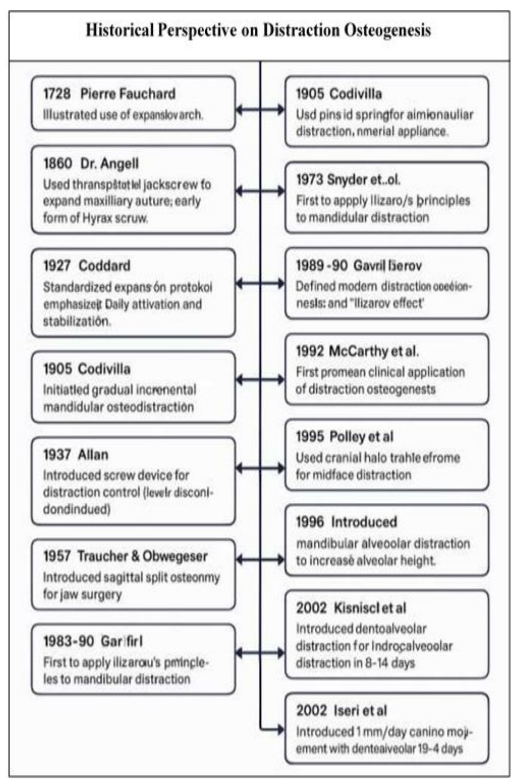
Facial asymmetry, mandibular hypoplasia, and congenital malformation of jaws are common abnormalities of the craniofacial complex.[5,6] Traditionally, skeletal deformities have been corrected via functional orthopaedics in growing patients or orthognathic surgery with skeleton fixation in non-growing patients.[7,8] Adaptation and stability of the adjacent muscles and soft tissues are one of the limitations and controversies related to orthognathic surgery and functional orthopaedics.

One of the major demerits of orthognathic surgery is that it permits only acute changes in the spatial arrangement of skeleton rather than provide de novo bone formation and which requires the needs of bone graft. It does not permit the change in shape and size of the bones to maximize the structural integrity, functional balance and esthetic of the patient.

CLINICAL RATIONALE FOR DISTRACTION OSTEOGENESIS

- Orthognathic surgery has gained a generalized acceptance for maxillo-mandibular deformity correction but several limitations are associated with it.
- One of the major limitations is the inability of the surrounding soft tissues to be acutely stretched. The surrounding soft tissues may not adapt to this new position thereby resulting in degenerative changes, relapse and compromised aesthetics and function.
- The other major factor is the limited possibility of new bone formation between the osteotomized segments in cases of severe deformities.
- This leads to the need of placement of a graft between the osteotomized segment to prevent relapse and to provide skeletal rigidity and stability.

Historical Perspective on Distraction Osteogenesis:



Indication and Contra-indication of Distraction Osteogenesis [9,10,11]

Indications and Relative Contraindications for Distraction Osteogeneseis	
Indications	**Relative Contraindications**
Midface Abnormalities • Maxilla and orbit advancement (LeFort I and III osteotomies) **Cleft Lip and Palate** • Alveolar gap closure **Lower Face Abnormalities** • Hemifacial mandibular microsomia (unilateral distraction • Mandibular hypoplasia • Severe mandibular retrognathia/micrognathia **Syndromic Conditions** • Pierre Robin syndrome (bilateral distraction) • Treacher Collins syndrome • Crouzon syndrome **Post-Traumatic Conditions** • TMJ ankylosis deficient growth post-trauma	• Poor nutritional status • Inadequate bone height and width • Old age • Osteoporosis • Necrotic / irradiated bone • Systemic disease (contraindicated for general anesthesia)

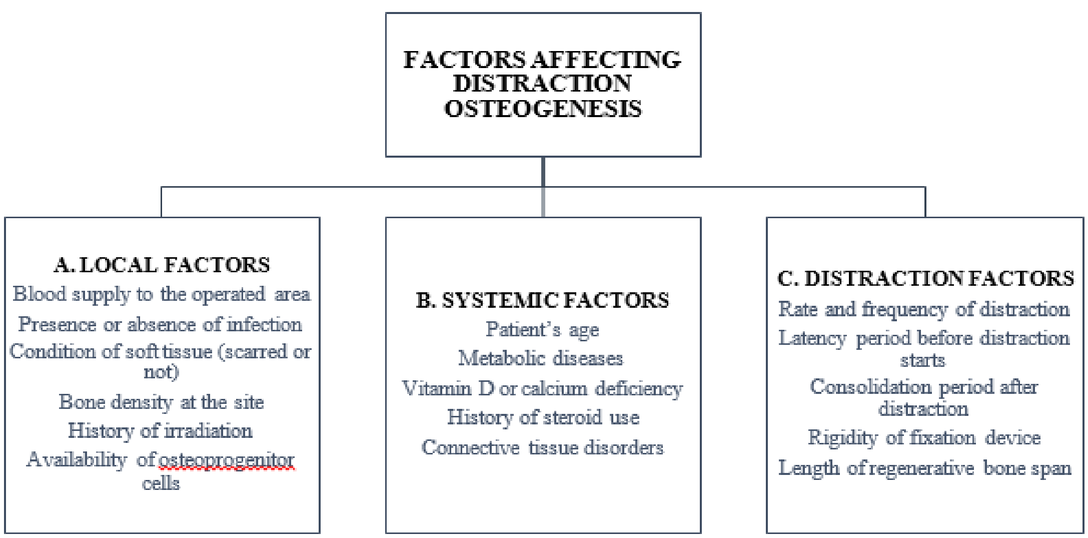
Advantages and Disadvantages of Distraction Osteogenesis [12-18]

Advantages	Disadvantages
Allows 10–30 mm mandibular lengthening with gradual soft tissue adaptation and minimal relapse	Skin scars (can be minimized by intraoral incisions)
Applicable to complex bony and soft tissue anatomy	Technique- and equipment-sensitive surgery
Effective in neonates, infants, and pediatric OSA patients	May require second surgery for device removal; requires patient compliance
Less invasive than bone grafting procedures	Transient TMJ changes
Avoids intermaxillary fixation	Adequate bone stock is required
No need for bone grafting or donor-site morbidity	Opposing surfaces must support callus formation
Enables mandibular widening	Risk of damage to tooth germ
Fewer adverse TMJ effects in asymmetric lengthening	Possibility of premature consolidation
Reduced hospital stay and lower cost compared to bone grafting	Risk of inferior alveolar nerve injury
Less need for blood transfusion	Potential for bilateral coronoid ankylosis
Wide age range applicability (children >2 years to adults)	Clockwise mandibular rotation tendency
Multiplanar and multidirectional distraction possible; minimal nerve damage	Does not address underlying growth disturbances

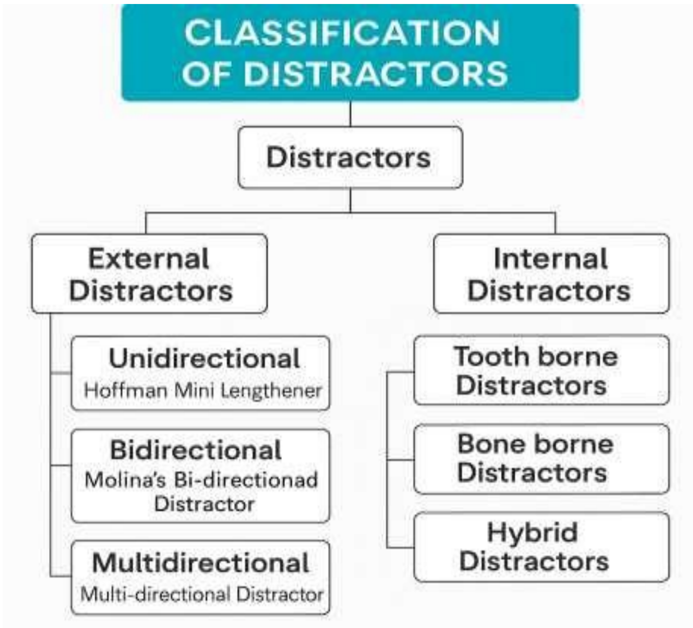
Complications Associated with Distraction Osteogenesis[19,20]

Phase	Complications
Intra-Operative	Bleeding or pain - Injury to nascent tooth bud by pin - Partial bone fracture - Nerve injury - Instability or breakage of the distraction device
During Distraction	Early bone calcification - Patient discomfort - Poor compliance with device use - Difficulty in eating - Infection around pins
Post-Distraction	Malunion or poor callus healing - Recurrence due to soft tissue pressure - Chronic nerve injury - Facial scarring from external devices - Temporomandibular joint (TMJ) issues - Altered speech
Shorter treatment duration than BSSO	Newly formed bone is less mineralized; devices can be bulky and uncomfortable
No extractions needed; better prognosis	High treatment cost

Factors Affecting Distraction Osteogenesis [21]



Classification of distractor devices :[22,23,24]



Unidirectional- The Hoffman Mini Lengthener device was introduced by McCarthy in 1989.(Fig.1) It was used for mandibular lengthening and was fixed externally. Device is adapted by rotation of clamp and sliding the other along the telescope distractor shaft.[25,26]

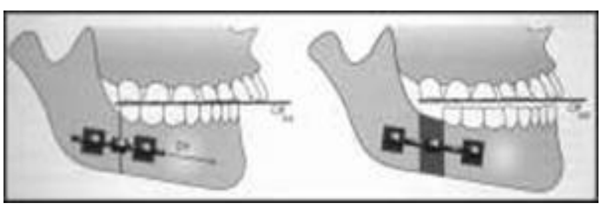


Fig 1. Unidirectional distractor

Bidirectional- Molinas Extraoral Distractor useful in cases with severe hypoplasia of mandible. Indication is post single or double osteotomy, distraction can be done both horizontally or vertically. It has two geared arms and a middle screw for changing angulation.[25] Extraoral Multi -Directional Distractor indicated in cases with midface development defects. In order to bridge the gap between the patient's diagnosis and the age at which they can have bimaxillary repositioning osteotomies, orthodontic preparation is required. Costochondral grafts are implanted in damaged mandibular locations in children.[26] Guerrero - Intraoral Device for Mandibular Widening first introduced in 1987, this was first device of its kind for widening mandible. (Fig. 2) A vertical symphyseal osteotomy is required prior and custom-made hyrax is placed. Activated 48 hours post-surgery and upon completion of distraction, acrylic is flowed around appliance to maintain expansion and stabilize it.[27]

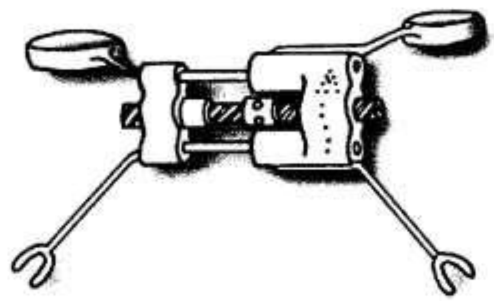


Fig 2. Bidirectional distractor

Distractor Orientation: The distraction device orientation is along the three vectors for distraction, namely, vertical, horizontal and oblique.[28] This is pictographically described in Figure 3.

Fig 3- Vectors of distraction a) vertical, b) horizontal and c) oblique

According to various planes in which distraction is carried out, they are subdivided into multiple models as follows:[29]

- **Model I-** Transverse plane- Distractor oriented parallel to lateral mandibular surface {fig 4. (A)}
- **Model II-** Transverse plane- Distractor oriented parallel to midsagittal axis and to each other as well {fig 4. (B)}
- **Model III-** Transverse plane- Distractor parallel to lateral mandibular surface {fig 4. (C)}

- **Model IV-** Transverse plane- Distractor parallel to each other {fig 4. (D)}
- **Model V-**Sagittal plane- Distractor at an angle to occlusal plane {fig 4. (E)}
- **Model VI-** Sagittal plane- Distractor parallel to occlusal plane {fig 4. (F)}

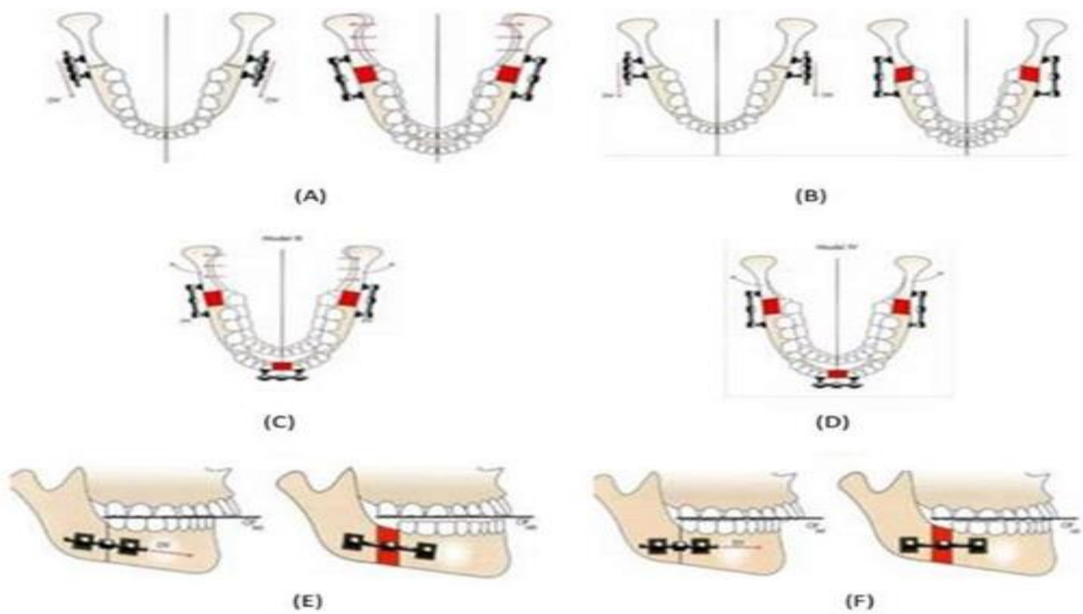


Fig 4 - (A) Model I Transverse plane (B) Model II Transverse plane (C) Model III Transverse plane (D) Model IV Transverse plane (E) Model V Sagittal Plane (F) Model VI Sagittal plane

Orthodontic Consideration:

PRE DISTRACTION ORTHODONTICS	DURING DISTRACTION OSTEOGENESIS	POST DISTALIZATION ORTHODONTICS
• For functional and cosmetic outcome. • Teeth to be positioned with respect to basal bone. • Distraction stabalizing appliance	• Bands , brackets , headgear, distraction stabilizing appliance, maxillary expansion appliance, functional appliance can be used.	• Distarction device is eliminated. • Newly produced bone across distratcion gap provides support for mandibular tooth bearing section.

Phases of Distraction Osteogenesis

Distraction process includes following fundamental sequential phases in which different biologic phenomenon is induced.

1. Osteotomy cut
2. Latency period
3. Distraction phase
4. Consolidation phase

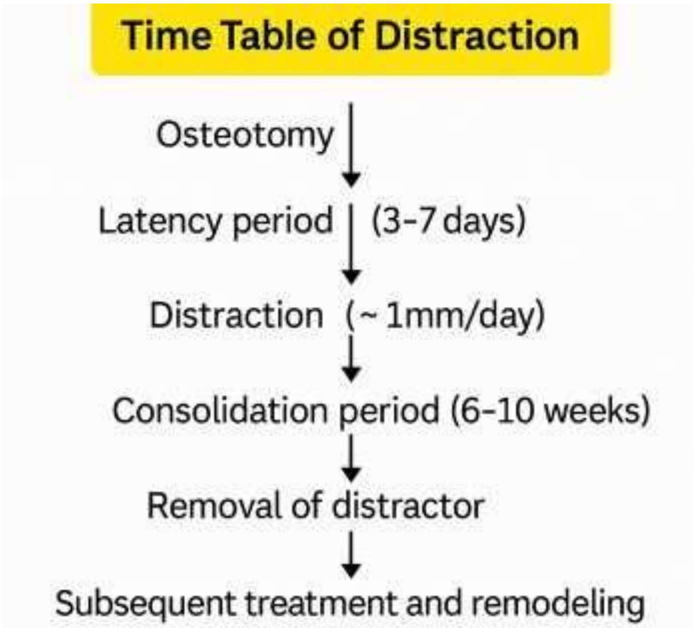


Fig 5 - The phases of distraction osteogenesis

According to Karp et al., at histologic level, the healing process in DO differs from that of a healing in fracture in two basic aspects.[30]

1. In DO controlled micro trauma is present in between distraction gap.
2. In DO, instead of endochondral ossification, membranous ossification occurs. In DO there are three sequential phases of different biologic phenomena: (Fig. 5)

- **Surgical phase -** In order to separate the segments while maintaining the medulla and periosteum's blood supply to the bone, a procedure known as a corticotomy involves performing an osteotomy to the cortical layer of the bone. The distraction rhythm in distraction osteogenesis indicates the frequency of the device activated each day, whereas the distraction rate reflects the daily displacement of the bone in millimetres (mm).

- **Latency period:** It is a time period between performed osteotomy and start of distraction. Latency period allows the surgical site to pass through the initial inflammatory stage of wound healing, into the reparative phase. This period varies from 0 to 7 days depending upon surgical trauma. During the latency period, restoration of bone is likely to be that observed after fracture i.e. hematoma formation, callus formation around (periosteal callus) and between (endosteal callus) the osteotomized bone segments. This callus tissue contains inflammatory cells, fibroblasts, a rich fibrin matrix, and collage, invading capillaries and cells with osteogenic potential. Accord ing to Macarthy distraction gap obviously is a hypoxic zone of injury which stimulates an angiogenic response and initiates the migration of primitive mesenchymal cells and the synthesis of collagen I matrix.

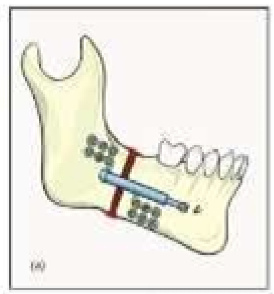


Figure 6.a) Latency phase which is preceded by surgical phase and in which hem atoma formation

Distraction period: This is the period in which traction is applied to the osteotomized bone and there is formation of new imma ture woven bone, fibers of which are parallel to distraction force. The typical protocol for distraction is 0.25 mm four times/day or at a rate of 1 mm/day.The stiff distraction device must be used in accordance with recommended protocol in order to achieve desired bone growth. By rotating an axial screw, which moves between 0.25 and 0.5 mm each turn (depending on the mechanism being utilized), the device is turned on. The soft callus may be stressed if the rate of distraction is too high, which could lead to thinning of all dimensions in the middle section of the regeneration and the formation of a "Hour Glass" at the distraction point. This has to distraction osteogenesis with how "Pulling Taffy Apart" works.[31] On the other hand, lower rate and frequency can result in early ossification, which would complicate the distraction inadvertently. Clinicians around the world often aim for a daily distraction rate of 1.0–1.5 mm and limit activation frequency to 2-4 times.

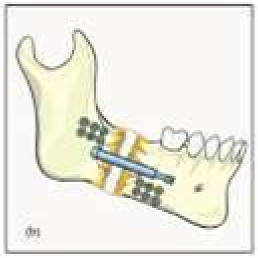


Figure 6.b)Distraction phase in which the bone gap is increased at margins by osteogenesis.

Consolidation period (neutro-fixation): In the period of consolidation mineralization of newly formed regenerate occurs. Usually, in the cases of craniofacial distraction the consolidation phase is of 6–12 weeks for adults. This phase comprises an extended period of immobility during which the stretched callus is supported by the device as it matures, maintaining the callus's stretched and stable posture and avoiding cartilaginous intermediate. The first step in remodelling is to provide lamella bone with elements of bone marrow time to develop. The consolidation period lasts between four and twelve weeks, on average eight weeks. According to clinical recommendations, the consolidation phase should last twice as long as the activation phase. The distraction site's location and the rate of bone metabolism determine when the consolidation period begins.[32]

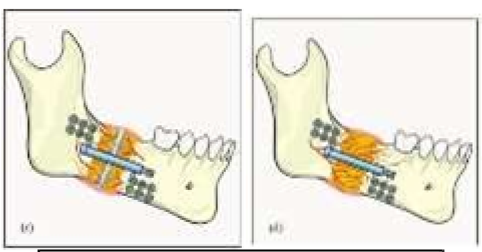


Figure 6. c) Consolidation phase, centre of bone gap experiences osteogenesis.
d) Late consolidation phase

Remodelling phase-This phase primarily consists of formation of lamellar bone. It is in this stage the distractor is removed after establishment of continuity bone &alveolar canal. The need for further intervention should be identified at earliest and also relapse should be checked in follow up visits which will ensure good prognosis.[33]

Bone formation and resorption both occur in distraction osteogenesis, so if process of bone resorption is blocked by antiresorptive agents such as bisphosphonates, hypothetically, it may lead to enhanced bone formation. Abbaspour et al. in their animal studies have recognized the positive effect of bisphosphonates in distraction process.

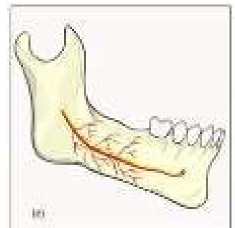


Figure 6.e) Remodelling phase, continuity of bone and alveolar canal established.

Recent Trends in Distraction Osteogenesis : [34-38]

- Internal Distraction Devices

Smaller, less invasive devices now used instead of bulky external distractors. Better patient comfort, hygiene, and esthetics.
Often resorbable or self-removing materials.

- 3D Planning & Navigation

3D imaging (CBCT) and CAD/CAM technology used for pre-surgical planning. Enables customized distractors and precise vector control.
Improved outcomes and reduced complications.

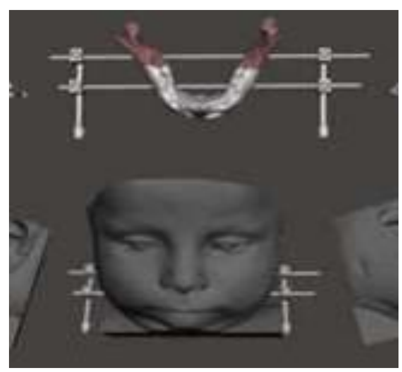


Fig 7. 3D planning & navigation

- Distraction in Paediatric Patients

Increasing use in craniofacial syndromes and cleft-related deformities. Earlier intervention possible due to minimally invasive techniques.

• Alveolar Ridge Distraction
Enhanced techniques for vertical bone augmentation in implantology. Supports dental implant placement in atrophic ridges.

• Distraction with Stem Cells & Growth Factors Tissue engineering integrated with DO.
Use of BMPs (Bone Morphogenetic Proteins) and MSCs (Mesenchymal Stem Cells) to accelerate bone regeneration.

• Accelerated Protocols
Research into shortened latency and consolidation periods using: Low-Level Laser Therapy (LLLT)
Pulsed Electromagnetic Fields Platelet-Rich Plasma (PRP)

• Distraction in Orthognathic Surgery
Used for severe skeletal discrepancies instead of traditional osteotomies. Hybrid techniques: combining DO with Le Fort and BSSO.

• Digital Monitoring & Remote Activation
Smart distractors in development: allow remote monitoring and activation. Increased precision and patient compliance.

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Review Article

Calcium Hydroxide in Endodontics- Properties, Clinical Applications and Recent Advances: A Review

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Abstract:
Calcium hydroxide [$Ca(OH)_2$] remains one of the most widely used materials in endodontics due to its excellent antimicrobial activity, biocompatibility, and ability to induce hard tissue formation. Since its introduction by Hermann in 1920, it has undergone various modifications in formulation and delivery. This review aims to provide a comprehensive understanding of calcium hydroxide, focusing on its mechanism of action, physicochemical properties, clinical applications with associated advantages and limitations, and recent technological and biological advancements that enhance its effectiveness.

Keywords: Calcium Hydroxide, Intracanal medicament, pulp capping, Root resorption

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INTRODUCTION

Calcium hydroxide ($Ca(OH)_2$) is a white, odorless, alkaline powder first introduced to dentistry by Hermann in 1920 (1). Since then, it has become an integral part of endodontic treatment, particularly in pulp therapy, root canal disinfection, and periapical healing. The wide spectrum of antimicrobial properties, high pH, and its potential to induce mineralized tissue make it a versatile intracanal medicament (2,3).

Its application spans direct and indirect pulp capping, apexogenesis, apexification, treatment of root resorption, regenerative endodontics, and as an intracanal medicament. It acts by releasing calcium and hydroxyl ions, which contribute to antibacterial action, neutralization of lipopolysaccharides, and promotion of mineralized barrier formation (2,4).

Despite the development of more advanced materials such as mineral trioxide aggregate (MTA), Biodentine, and bioceramic sealers, calcium hydroxide remains relevant in clinical endodontics. This review discusses its mechanisms, physicochemical properties, clinical applications, recent innovations, and future prospects, with emphasis on postgraduate-level understanding.

MECHANISM OF ACTION

The efficacy of calcium hydroxide in endodontics primarily depends on its dissociation into calcium (Ca^{2+}) and hydroxyl (OH^-) ions (2,5). These ions are responsible for its biological and antimicrobial actions:

High Alkalinity: With a pH of approximately 12.5, calcium hydroxide creates an environment unfavorable to most microorganisms. The hydroxyl ions are highly reactive and damage bacterial DNA, proteins, and cytoplasmic membranes (2,6).

Antibacterial Activity: Its effectiveness is well-documented against anaerobic bacteria commonly found in infected root canals. However, resistance has been observed with Enterococcus faecalis and Candida albicans due to their ability to survive in high pH environments (7,8).

Neutralization of Lipopolysaccharides (LPS): Hydroxyl ions inactivate bacterial endotoxins like LPS, which are responsible for triggering inflammatory responses in periapical tissues (5).

Tissue Induction and Healing: Calcium ions act as messengers that promote differentiation of stem cells into odontoblast-like cells, stimulating tertiary dentin or hard tissue barrier formation (6,9).

PHYSICOCHEMICAL PROPERTIES

1.Solubility: Slightly soluble in water (1.73 g/L at 20°C), releasing calcium and hydroxyl ions over time (10).

2. pH: Produces an alkaline environment with a pH of 12.5, critical for its antibacterial and tissue-stimulating properties (2).

3. Ion Dissociation: Essential for biological function; hydroxyl ions contribute to antimicrobial action, while calcium ions stimulate tissue repair (6).

4. Diffusion Through Dentin: Calcium hydroxide diffuses through dentinal tubules, affecting deep bacterial colonies and surrounding tissue. Its diffusion ability depends on dentin thickness and presence of smear layer (10,11).

CLASSIFICATION AND VEHICLES

Calcium hydroxide ($Ca(OH)_2$) is a widely used intracanal medicament in endodontics due to its high alkalinity, antimicrobial properties, and ability to stimulate hard tissue formation. The effectiveness of calcium hydroxide largely depends on the vehicle used, which influences its ion release, solubility, and diffusion into dentinal tubules.

Calcium hydroxide preparations are broadly categorized based on setting time (fast, slow, or no setting), curing method (self-cure, light-cure), and vehicle type:

1. **Aqueous Vehicles**
   Examples: Water, saline, anesthetic solution These allow rapid dissociation of calcium and hydroxyl ions, providing a quick rise in pH and strong antimicrobial action.

   Commercially available as: **RC Cal** (Prime Dental) ,**ApexCal** (Ivoclar Vivadent), **Calasept Plus**

- **Advantages:**
- Quick ionic dissociation
- Faster antimicrobial activity
- Easy placement and removal

- **Disadvantages:**
- Rapid solubility and resorption

- Short duration of action
- Requires frequent replacement

2. Viscous Vehicles
Examples: Glycerin, polyethylene glycol (PEG), propylene glycol
These allow moderate and sustained ion release, providing a longer duration of activity.

- **Advantages:**
- Sustained release of ions
- Longer intracanal retention
- Better control over placement

- **Disadvantages:**
- May have reduced immediate antimicrobial effect compared to aqueous types
- Slightly more difficult to remove

Commercially available as: **Calen** (SS), **Hydropast** (Biodinamica Quimica), **Calcipulpe** (Septodent)

3. Oily Vehicles
Examples: Silicone oil, olive oil, camphorated monochlorophenol (CMCP)
These promote the slowest ion dissociation, making them suitable for long-term use.

- **Advantages:**
- Long-term stability in the canal
- Low solubility
- Minimal need for replacement
- **Disadvantages:**
- Delayed antimicrobial action
- Difficult to remove from canal
- May interfere with obturation if not completely cleared

The choice of vehicle should be case-specific. Acute infections may benefit from aqueous formulations, while chronic conditions requiring long-term action may be better managed with viscous or oily vehicles[12].

Commercially available as: **Metapex** (Meta Biomed) , **Vitapex** (Neo Dental)
Light-Cured Calcium Hydroxide is a radiopaque, resin-based liner that releases calcium ions to promote secondary dentin formation and provide a protective barrier over exposed pulp or deep dentin. Unlike conventional self-cure calcium hydroxide, light-cured formulations offer improved physical properties, better adhesion to dentin, and controlled setting time upon light activation. They are commonly used under composite restorations, in indirect pulp capping, and as a base/liner in deep cavities.

Commercially available light-cured calcium hydroxide materials include **Calcimol LC (VOCO)**, **Ultra-Blend Plus (Ultradent)**, **Ionoseal (VOCO)**, and **Dycal LC (Dentsply)**.

CLINICAL APPLICATIONS:

1. Direct Pulp Capping:
Involves the application of calcium hydroxide directly on exposed pulp to maintain vitality and promote healing. It stimulates reparative dentin formation and provides a protective barrier [8,13].

Advantages:
- Stimulates dentin bridge formation
- Antibacterial and anti-inflammatory
- Biocompatible and economical Long history of clinical use [3,8]

Disadvantages:
- Formation of tunnel defects in the dentin bridge
- Poor long-term seal
- Disintegration over time
- Less predictable compared to MTA [12,14]

2. Indirect Pulp Capping
This technique involves placing calcium hydroxide over a thin layer of affected dentin to avoid pulp exposure while allowing healing and tertiary dentin formation [3].

Advantages:

- Maintains pulp vitality
- Arrests caries progression
- Stimulates odontoblastic activity
- Simple and cost-effective [8]

Disadvantages:

- Requires careful monitoring
- No adhesive bond
- Risk of microleakage
- Less durable than newer materials [12,14]

3. Apexogenesis

Apexogenesis is a vital pulp therapy for immature teeth with vital pulp. The aim is to preserve pulp vitality to allow continued root development and apical closure. Calcium hydroxide has been a traditional choice due to its ability to stimulate hard tissue formation and its antibacterial properties [6,13].

Advantages:

- Encourages root maturation and apical closure
- Preserves pulp vitality
- Antibacterial and anti-inflammatory
- Widely used and studied technique (3,12)

Disadvantages:

- Risk of pulp necrosis
- Requires multiple visits and long-term follow-up
- Dentin bridge may have tunnel defects
- Less effective compared to MTA in maintaining long-term outcomes [14,15]

4. Apexification

Apexification is performed in non-vital immature teeth to induce the formation of a calcific barrier at the apex. Traditionally, calcium hydroxide is placed in the canal over several months to stimulate this barrier [3,11].

Advantages:

- Non-surgical, conservative technique
- Long-term clinical success in forming an apical barrier
- Cost-effective material [11,16]

Disadvantages:

- Prolonged treatment time (up to 6–24 months)
- Increased risk of root fracture due to long-term exposure (17)
- Requires patient compliance for follow-up
- MTA has largely replaced $Ca(OH)_2$ in modern apexification [12,14]

5 Intracanal Medicament

Calcium hydroxide is frequently used as an interappointment medicament in infected canals. Its high pH helps in microbial control and endotoxin neutralization [2,4].

Advantages:

- Broad-spectrum antimicrobial action
- Inhibits bacterial endotoxins (e.g., LPS)
- Controls periapical inflammation
- Easy to remove from canals [5,8]

- **Disadvantages:**
- Ineffective against E. faecalis and C. albicans
- Biofilm resistance observed
- May weaken dentin structure with prolonged use (7,14,17)
- Incomplete removal can interfere with sealers [10,15]

6. Management of Root Resorption(External and Internal)

Calcium hydroxide is effective in arresting internal and external inflammatory root resorption by altering osteoclastic activity and neutralizing the acidic environment [3,4].

Advantages:

- Inhibits resorptive process
- Anti-inflammatory effect
- Promotes hard tissue repair
- Easily available and affordable [3,13]

Disadvantages:

Needs regular dressing changes
Limited efficacy in severe resorption

Solubility can compromise the seal
Prolonged use risks dentin weakening [16,18]

7. In prevention of Ankylosis:
Calcium hydroxide is widely used as an intracanal medicament in the management of reimplanted teeth, particularly in cases of delayed reimplantation where the risk of root resorption and ankylosis is high due to prolonged extra-oral dry time and necrosis of periodontal ligament (PDL) cells. It is primarily indicated in permanent teeth with closed apices that have undergone avulsion and are expected to develop pulp necrosis.

The principal mechanism of action of calcium hydroxide lies in its high alkaline pH (~12.5), which creates an environment that inhibits the survival and activity of osteoclasts responsible for inflammatory root resorption.

Clinically, calcium hydroxide is placed inside the cleaned and shaped root canal after reimplantation, especially in cases where the tooth has been dry for more than 60 minutes. It remains in the canal for 2 to 4 weeks, during which it exerts its anti-resorptive and disinfecting effects.

Advantages:
- Potent antibacterial activity
- Ability to induce hard tissue formation
- Low cost
- Biocompatibility

Disadvantages:
- Prolonged exposure can weaken root dentin
- Increased risk of root fractures
- Reduced flexural strength.

8. In Weeping Canals:
Weeping canals are characterized by persistent serous exudation from the root canal system, commonly seen in necrotic teeth with chronic apical periodontitis or abscess. This condition prevents canal drying and obturation in a single visit.

Calcium hydroxide is the preferred intracanal medicament in such cases due to its:
- Strong alkaline pH (~12.5), which neutralizes bacterial endotoxins (like LPS)
- Potent antimicrobial and anti-inflammatory action
- Ability to dry canal spaces by desiccating inflamed tissue
- Stimulation of periapical healing

It is typically applied as a paste for 1–2 weeks, with repeat placement if exudation persists. Vehicles like viscous (e.g., propylene glycol) or oily bases (e.g., Metapex) enhance its retention and efficacy.

Advantages:
- Facilitates canal drying
- Reduces inflammation
- Promotes healing
- Enables future obturation.

Disadvantages:
- Requires multiple visits
- May weaken dentin if overused
- Prolonged exudation may indicate more complex pathology.

9. As Root Canal Sealer:
Calcium hydroxide has been incorporated into root canal sealers to enhance their antimicrobial activity and bioactivity. These sealers are either calcium hydroxide-based or contain $Ca(OH)_2$ as an additive. Examples include Sealapex, Apexit, and Metapex-based sealers. These are used alongside gutta-percha to fill voids, lateral canals, and accessory canals during obturation [3,10].

Mechanism of Action:
When used in sealer form, calcium hydroxide:
- Releases Ca^{2+} and OH^- ions, which elevate pH and exhibit bactericidal action
- Promotes periapical healing by stimulating mineralized tissue formation
- Neutralizes residual toxins, especially in uninstrumented areas
- Enhances biocompatibility at the apex and prevents periapical irritation [4,9,10]

Advantages:
- Antibacterial effect due to sustained high pH
- Biocompatibility superior to zinc oxide–based sealers
- Induces tissue repair, making it useful in cases with periapical involvement
- Radiopaque and easy to handle
- Available in paste or injectable forms, allowing easy manipulation (10,12)

Disadvantages:
- Solubility in tissue fluids, which may lead to leakage or loss of seal over time
- Weak bonding to dentin compared to resin or bioceramic sealers
- May exhibit shrinkage on setting, especially in early calcium hydroxide sealers
- Incompatibility with some resin-based materials due to residual alkalinity (15,16)

10. As a Liner

Calcium hydroxide is widely used as a protective liner in deep cavity preparations where the remaining dentin is thin. As a liner, it is placed in minimal thickness over areas closest to the pulp to prevent irritation from restorative materials and to stimulate dentin formation (3,6)

Mechanism of Action:
When used as a liner, calcium hydroxide exerts:

Antibacterial activity through its high pH
Stiulation of odontoblast-like cells, leading to tertiary (reparative) dentin formation
Chemical protection against acidic components of dental materials (8,9)

Advantages:
- Biocompatible and non-toxic to pulp
- Promotes dentin bridge formation
- Inexpensive and easy to apply
- Provides antibacterial protection under restorations **(6)**

Disadvantages:
- Low compressive strength and prone to disintegration
- Incompatible with resin-based materials unless covered with a protective base
- May degrade over time under large occlusal forces
- Potential for tunnel defects in formed dentin, allowing bacterial infiltration (12,14)

11. Calcium Hydroxide in Pulpotomy

Pulpotomy is a vital pulp therapy procedure performed in teeth with reversible pulpitis, especially in primary teeth and young permanent teeth. Calcium hydroxide has long been used for full coronal pulpotomies, especially in immature teeth to allow continued root development (3,8,13).

Mechanism of Action:
Calcium hydroxide induces a high pH inflammatory response, resulting in:

Superficial necrosis of pulp tissue
Beneath which, a hard tissue barrier (dentin bridge) forms Preservation of radicular pulp vitality
Continued root maturation in young permanent teeth (6,13)

Advantages:
- Cost-effective and readily available
- Stimulates dentin bridge formation
- Non-toxic and pulp-friendly
- Useful in apexogenesis of immature teeth (13)

Disadvantages:
- High failure rate in primary teeth due to chronic inflammation and internal resorption
- Inferior to materials like MTA or Biodentine in long-term success
- Formation of dentin bridge with tunnel defects, which can compromise pulp sealing
- Limited success in large or irreversible pulp exposures (12,14)

RECENT ADVANCES IN CALCIUM HYDROXIDE USE IN ENDODONTICSNTRODUCTION

Calcium hydroxide ($Ca(OH)_2$) continues to evolve through technological innovations aimed at overcoming its traditional limitations such as limited antimicrobial spectrum, rapid solubility, and lack of long-term sealing. Recent developments have enhanced its application in both conventional and regenerative endodontics.

1. Nanoparticle Formulations

Nanotechnology has introduced nano-calcium hydroxide, which has significantly improved surface area and diffusion potential. These particles penetrate deeper into dentinal tubules and biofilms, enhancing antibacterial efficacy against E. faecalis and Candida albicans (14,21). Additionally, their improved alkalizing capability leads to a more potent antimicrobial environment without increasing cytotoxicity (21).

2. Advanced Drug Delivery Vehicles

Innovative carriers have replaced conventional vehicles to provide controlled and sustained ion release. These include:

Hydrogels(e.g., chitosan, PEG)
Polymeric microsphere (e.g., polylactic acid, PCL)
Nanofiber scaffolds

These systems prolong the release of calcium and hydroxyl ions, improve tissue compatibility, and reduce the frequency of redressing, particularly useful in apexification and regenerative procedures (16,20).

3. Antimicrobial Combinations

Combining $Ca(OH)_2$ with other agents has demonstrated enhanced antimicrobial efficacy:

Chlorhexidine (CHX): Improves substantivity and biofilm penetration (18)
Curcumin or quercetin: Adds anti-inflammatory and antioxidant effects (22)
Silver/zinc nanoparticles: Broaden the antimicrobial spectrum and target resistant pathogens (21)
Calcium hydroxide-antibiotic blends (e.g., with metronidazole): show synergistic bacterial inhibition in polymicrobial infections (24)

These combinations improve outcomes in persistent infections, especially those involving biofilm-forming organisms.

4. Compatibility with Bioceramics and Sealers

Recent studies have explored bioceramic-enhanced calcium hydroxide formulations, combining the mineralizing and antibacterial properties of $Ca(OH)_2$ with superior sealing ability of bioceramic matrices (16). Modified forms with improved resin compatibility also aim to prevent the interference of residual $Ca(OH)_2$ with root canal sealers (15).

5. Regenerative Endodontics Applications

Calcium hydroxide plays a critical role in regenerative endodontic procedures (REPs) due to its ability to inactivate endotoxins and maintain low cytotoxicity. Modified formulations have been developed to preserve stem cell viability — particularly of SCAP and DPSCs — while still providing adequate disinfection (13,19). This makes $Ca(OH)_2$ a viable alternative to triple antibiotic paste in specific regenerative cases.

6. Enhanced Activation Techniques

To improve its action, $Ca(OH)_2$ can now be ultrasonically agitated or laser-activated (e.g., with Nd\:YAG or diode lasers), increasing its penetration into lateral canals and dentinal tubules. These techniques also enhance pH elevation and microbial elimination from inaccessible areas (20,23).

7. Biointeractive and Buffered Formulations

Recent buffered versions of $Ca(OH)_2$ aim to control pH levels to reduce cytotoxicity while maintaining antimicrobial action. These formulations show promise in long-term intracanal use without significantly affecting periapical tissues (14,19).

8. Imaging and Monitoring Tools

Advancements in real-time imaging have improved our understanding of $Ca(OH)_2$ dynamics:

Confocal Laser Scanning Microscopy (CLSM) for ion penetration
Micro-CT to visualize dissolution and dentin interface
Ion-selective electrodes to monitor pH gradients and calcium release

These tools offer precise assessment of the medicament's efficacy and biological interactions (15,21).

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Efficacy of Zinc Oxide-Ozonated Oil as an Obturating Material in Primary Teeth: A Narrative Review

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Abstract:
In order to save carious primary teeth until their natural exfoliation and retain the structure and function of the arch, pulpectomy is still a fundamental treatment in Pediatric dentistry. The mechanical and biological characteristics of the obturating substance utilized have a significant impact on the pulpectomy's long-term success. The conventional option of zinc oxide-eugenol (ZOE) has drawbacks such cytotoxicity and delayed resorption. The powerful antibacterial, anti-inflammatory, and healing-promoting qualities of zinc oxide-ozonated oil (ZnO-OO) have drawn attention recently. This review compares the performance of ZnO-OO with both established and novel materials, combining the recent data from four important in vivo investigations. ZnO-OO is an appealing option for juvenile endodontics because of its high clinical and radiographic success, remarkable biocompatibility, and exceptional handling qualities, as shown by consistent results.

Keywords: Narrative Review, Obturating Material, Pediatric Dentistry, Pulpectomy, Zinc Oxide Ozonated Oil

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INTRODUCTION:

Mastication, phonation, aesthetics, and directing the emergence of permanent teeth are all critical functions of primary teeth. It is crucial to keep these teeth intact until their natural exfoliation, particularly if pulp diseases are present. Pulpectomy is recommended when primary teeth exhibit permanent pulpitis or necrosis. This procedure entails total debridement and obturation of the root canal system. The optimal obturating material should be radiopaque, biocompatible, resorbable, antibacterial, and easy to apply without interfering with succeeding eruption.

Because of its antibacterial properties and track record of dependability, zinc oxide-eugenol (ZOE) has been utilized extensively. Nevertheless, it may not resorb as quickly as primary roots and may remain in the periapical area, which may interfere with the permanent successors' eruptive route and result in periapical inflammation1. Furthermore, at high doses, the eugenol component is cytotoxic2,3,4.

Alternative materials like calcium hydroxide, iodoform-based pastes (like Vitapex), herbal formulations, and biologically inspired combinations like 3Mix have been investigated as a result. Because of its biological qualities, which include antibacterial activity, debriding impact, angiogenesis promotion, anti-inflammatory and analgesic effects, and immunological response enhancement, ozone, -a strong oxidizing agent, has been hailed as promising.5 Among these, zinc oxide-ozonated oil (ZnO-OO) has emerged as a novel and promising option, combining the mechanical properties of ZnO with the biological efficacy of ozone.

Mechanism and Rationale of Zinc Oxide-Ozonated Oil

Ozonated vegetable oils, including ozonated olive or sesame oil, are mixed with zinc oxide powder to create ZnO-OO, a thick, malleable paste. Ozone is stabilized by the ozonated oil as ozonides and peroxides, which over time gradually release reactive oxygen species (ROS) like singlet oxygen and nascent oxygen.6,7 These substances have broad-spectrum antibacterial properties because they break down microbial cell walls, obstruct DNA synthesis, and suppress protein metabolism.

Furthermore, ozone promotes collagen synthesis, fibroblast proliferation, oxygen supply, and local blood flow, all of which hasten the healing of periapical tissues.8 The oil base facilitates simple insertion into the root canal with few voids and guarantees long-lasting antibacterial activity. Thus, the oil basis, which serves as an antibacterial vehicle, and ozone, which encourages healing, can combine to provide the perfect obturating material for primary teeth.

Clinical Evidence Overview

This review analyzes four in vivo studies that provide substantial clinical and radiographic data on ZnO-OO:

El-Desouky et al., 20233

- **Design:** Randomized controlled trial (90 molars, 3 groups)
- **Materials:** ZnO-OO, ZnO with olive oil, ZOE
- **Follow-up:** at 3, 6, 12 months
- **Results:** ZnO-OO had a 92.6% clinical success rate and superior furcation bone healing. ZOE had lower success (82.1%) and more postoperative complications.
- **Conclusion:** ZnO-OO showed improved biocompatibility and healing.

Doneria et al., 2017[4]

- **Design:** In vivo comparative study (64 molars)
- **Materials:** ZnO-OO, modified 3Mix-MP, Vitapex
- **Results:** ZnO-OO and Vitapex achieved 100% clinical and radiographic success; 3Mix was inferior (95.8% and 79.2%, respectively).
- **Conclusion:** ZnO-OO demonstrated reliable outcomes with minimal internal resorption.

Vachhani et al., 2022[6]

- **Design:** Randomized controlled trial (90 molars)
- **Materials:** ZnO-OO, ZnO-Ocimum sanctum, ZOE
- **Results:** ZnO-OO: 95.7% clinical, 91.3% radiographic success; outperformed ZOE and herbal alternatives.
- **Conclusion:** Ozonated oil's unique properties enhance healing and reduce cytotoxicity.

Arora et al., 2024[7]

- **Design:** In vivo comparative study (120 molars)
- **Materials:** ZnO-OO, ZOE, Probiotic mix, Antioxidant mix
- **Results:** ZnO-OO showed highest success and lowest postoperative discomfort.
- **Conclusion:** ZnO-OO surpassed other novel obturating alternatives.

Summary of Study Outcomes

Study Groups Compared Best Performing Material Clinical Success (%) Radiographic Success (%)

Study	Groups Compared	Best Performing Material	Clinical Success (%)	Radiographic Success (%)
El-Desouky et al. 2023	ZnO-OO, ZOE, ZnO-Olive	ZnO-OO	92.6	Significantly higher
Doneria et al. 2017	ZnO-OO, 3Mix, Vitapex	ZnO-OO = Vitapex	100	100
Vachhani et al. 2022	ZnO-OO, ZOE, Ocimum	ZnO-OO	95.7	91.3
Arora et al. 2024	ZnO-OO, ZOE, Probiotic, Antioxidant	ZnO-OO	88.9	96.3

DISCUSSION

Compared to ZOE, ZnO-OO exhibits significantly lower cytotoxicity, especially because eugenol is not present. Research validates safe resorption patterns and a low inflammatory response (pain, abscess, movement, discomfort on percussion, and lymphadenopathy).4,6

Ozone offers a potent, non-antibiotic antimicrobial strategy, effective against bacteria, fungi, and viruses. It avoids the development of resistance and is suitable for Pediatric patients7,9. Ozone can be successfully incorporated to dental materials by using it in a variety of formulations, such as ozonated oils or gels. Ozonated oil can be a perfect obturating agent when mixed with an appropriate base, such as zinc oxide. The oil base aids in transport and sealing qualities, while the ozone enhances antimicrobial activity. When combined, they create a biocompatible substance that complements the primary teeth's physiological resorption rate and keeps the treatment intact until the exfoliation process happens naturally.

All studies report reduced interradicular radiolucencies and increased bone density at follow-up intervals, reflecting active tissue regeneration and periapical repair3,6. At subsequent follow-up intervals, every study consistently reports a discernible improvement in bone density and a discernible decrease in interradicular radiolucencies. These radiography results show a positive healing response, indicating that the obturating material supports the biological processes required for periapical repair in addition to maintaining an aseptic environment within the root canal system. The progressive disappearance of radiolucencies suggests that infection and inflammation have been successfully eradicated, enabling the restoration of normal bone remodeling. Active tissue regeneration is highlighted by the concurrent increase in radiopacity in previously impacted areas, which indicates the production of new bone.

The ZnO-OO paste is simple to prepare, flows easily in canals, and sets under moist conditions, meeting key criteria for Pediatric endodontic materials6,7. It has useful benefits that make it especially appropriate for usage in Pediatric endodontics. It is easier to use in standard clinical settings because it is simple to prepare, needing few steps and no complicated equipment. After preparation, the paste has outstanding flow characteristics that enable it to conform effectively to the complex structure of primary root canals, guaranteeing complete filling without applying undue pressure. Given the prevalence of narrow canals and anatomical heterogeneity in Pediatric dentistry, this trait is extremely beneficial.

Long-term effectiveness is maintained by ZnO-OO without leading to issues such as internal resorption, over-retention, or interference with successor eruption. It is better than biologics and herbals because of its predictability.

The integration of ozone into zinc oxide not only enhances the antimicrobial efficacy of the obturating material but also contributes to its exceptional biocompatibility, making it an ideal material for primary teeth. The absence of eugenol reduces cytotoxic effects, while the natural resorption compatibility ensures minimal interference with physiological processes. The consistent reduction in interradicular radiolucencies and increased bone density across studies strongly supports its regenerative potential. ZnO-OO's ease of preparation, flow properties, and moisture-setting capability align perfectly with the anatomical and clinical demands of pediatric endodontics. Unlike some biologic or herbal alternatives, ZnO-OO provides predictable outcomes with minimal complications such as internal resorption or delayed exfoliation. Collectively, these properties position ZnO-OO as a superior, next-generation obturating material that not only treats infection but also promotes healing and tissue restoration in primary teeth.

CONCLUSION

Zinc oxide-ozonated oil (ZnO-OO) is a novel obturating material in pediatric endodontics that exhibits superior clinical and radiographic performance, enhanced biocompatibility, and ease of application when compared to conventional materials like ZOE, Vitapex, 3Mix, and herbal agents.
Its notable antimicrobial activity and regenerative potential make it a compelling candidate for routine use in pulpectomy procedures for primary teeth. These properties suggest it could improve treatment outcomes and reduce failure rates associated with traditional materials.

Although current evidence is promising, widespread clinical adoption should follow only after further validation through multicentric randomized trials, long-term follow-up studies, and detailed histological assessments.

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Jaw Morphodynamics and Modjaw Technology: Revolutionizing Dental Diagnostics

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Abstract:
Jaw Morphodynamics and Modjaw Technology: Revolutionizing Dental DiagnosticsUnderstanding the dynamic function of the temporomandibular joint (TMJ) and jaw movement patterns is central to achieving successful occlusal, prosthetic, and orthodontic outcomes. Conventional diagnostic tools often fall short, capturing only static anatomical relationships. The emergence of jaw morphodynamics as a diagnostic approach, alongside the introduction of Modjaw—a 4D motion-tracking technology—marks a paradigm shift in dental evaluation and treatment planning. Modjaw captures functional mandibular movement in real-time, providing clinicians with an advanced, data-driven foundation for diagnosis and intervention. This review explores the evolution of jaw morphodynamics, the technical capabilities of Modjaw, and their combined role in transforming modern dental diagnostics and patient care.

Keywords: Jaw Morphodynamics, Modjaw Technology, 4D Jaw Tracking, Functional Occlusion, Digital Dentistry.

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INTRODUCTION:

The advent of digital technology has revolutionized the field of dentistry, transforming traditional diagnostic and treatment methodologies into precision-driven, data-centric approaches. Among the many innovations reshaping clinical practice, jaw morphodynamics and the application of Modjaw technology stand out as significant advancements. Jaw morphodynamics is the study of the functional movements of the jaw and how these movements are influenced by anatomical structures, physiological changes, and pathological conditions. It encompasses the dynamic interplay between the mandible, maxilla, temporomandibular joints (TMJs), and masticatory muscles during functions such as chewing, speaking, and swallowing. Understanding these dynamics is essential not only for diagnosing disorders but also for planning restorative, orthodontic, and prosthetic treatments that align with a patient's functional anatomy.1 Historically, the assessment of jaw movement relied on static models and mechanical articulators, which simulated occlusal relationships based on impressions and casts. While these tools provided foundational insights, they lacked the capacity to capture the real-time, patient-specific movements of mandibular motion. This limitation posed challenges in accurately diagnosing temporomandibular disorders (TMD), planning complex restorations, and ensuring long-term treatment success. The emergence of Modjaw technology addresses these gaps by offering a dynamic, high-resolution view of jaw movement. Utilizing infrared sensors and advanced software, Modjaw records and analyzes the three-dimensional motion of the jaw in real time, creating a digital twin of the patient's functional anatomy.2

This technology integrates intraoral scans, facial scans, and motion capture data to deliver a comprehensive representation of jaw dynamics. Its real-time capabilities enable clinicians to assess occlusion, identify dysfunctions, and tailor treatments with unprecedented precision. Whether optimizing the design of a crown, aligning orthodontic appliances, or diagnosing TMJ anomalies, Modjaw facilitates a new standard of care that prioritizes individualized, data-informed decision-making. As dental professionals increasingly embrace digital workflows, Modjaw represents a critical tool in the pursuit of improved diagnostic accuracy, enhanced treatment outcomes, and elevated patient satisfaction.3 This explores the fundamental concepts of jaw morphodynamics and delves into the transformative role of Modjaw technology in contemporary dental diagnostics and treatment planning.

UNDERSTANDING JAW MORPHODYNAMICS

The human jaw is a complex system involving the mandible, maxilla, temporomandibular joint (TMJ), and surrounding musculature. The TMJ, a bilateral synovial joint, allows for a range of motions including rotation, translation, and lateral deviation. These movements are governed by muscles such as the masseter, temporalis, and pterygoids, which work in coordination to facilitate functions like mastication and speech. Morphodynamics examines how these structures adapt over time due to factors like growth, aging, dental interventions, or pathological conditions.4

Traditional methods for studying jaw movement relied on physical articulators—mechanical devices that simulate jaw motion based on static impressions. While useful, these tools lack the ability to capture real-time dynamics and individual variability. Conditions like temporomandibular disorders (TMD), characterized by pain, clicking, or restricted movement, require precise diagnostics to identify underlying causes, such as muscle imbalances or joint misalignment. Similarly, restorative dentistry, orthodontics, and prosthodontics demand accurate data on jaw motion to ensure optimal outcomes. This is where technologies like Modjaw bridge the gap, offering dynamic, patient-specific insights.3,5

Modjaw is a digital diagnostic tool developed to record and analyse jaw movements in real time, combining motion capture technology with 3D dental imaging. Unlike traditional articulators, Modjaw uses advanced sensors and software to track mandibular motion with high accuracy, creating a virtual model of the patient's jaw dynamics. The system integrates intraoral scans, facial scans, and motion data to produce a comprehensive digital representation of the patient's occlusion and jaw function.

Modjaw employs infrared cameras and lightweight markers placed on the patient's face to track mandibular movements. This non-invasive approach records trajectories during chewing, speaking, and other functional activities. The system combines motion data with 3D scans of the teeth and face, allowing clinicians to visualize how jaw movements interact with dental anatomy. Modjaw provides detailed insights into occlusal contacts, identifying points of interference or imbalance that could lead to wear, fractures, or discomfort. By simulating jaw movements, Modjaw enables clinicians to design restorations, orthodontic appliances or prosthetics tailored to the patient's unique dynamics. The system also allows for easy sharing of digital models with dental laboratories, ensuring precise fabrication of restorations.2,7,8.

MECHANISM

The Modjaw workflow begins with the placement of small, non-invasive markers on the patient's face, typically around the chin and forehead. These markers are tracked by infrared cameras as the patient performs natural jaw movements. Simultaneously, intraoral scanners capture detailed 3D images of the teeth, while facial scanners map the external anatomy. The Modjaw software processes this data, aligning the motion trajectories with the 3D models to create a dynamic digital twin of the patient's jaw.

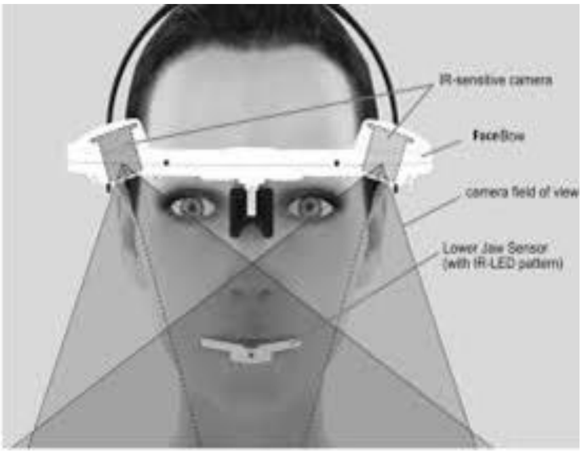

Fig. 1 Working mechanism of Modjaw

Clinicians can then analyze the data to assess parameters such as condylar path, incisal guidance, and occlusal contacts. The software also allows for virtual simulations, enabling dentists to test treatment outcomes before implementing them. For example, a dentist designing a crown can use Modjaw to ensure the restoration aligns with the patient's natural bite dynamics, reducing the risk of post-treatment complications.

Modjaw's ability to capture and analyze jaw morphodynamics has far-reaching implications across various dental specialties.In the diagnosis and management of temporomandibular disorders (TMD), which affect millions of people worldwide and cause symptoms like jaw pain, headaches, and restricted movement, Modjaw's precise tracking of mandibular motion helps clinicians identify abnormal patterns, such as asymmetrical condylar movement or restricted translation. By visualizing these dynamics, dentists can develop targeted treatment plans, including splint therapy, physical therapy, or surgical interventions.5,7

In restorative dentistry, procedures like crowns, bridges, and veneers require achieving proper occlusion to prevent premature wear or failure. Modjaw allows dentists to design restorations that harmonize with the patient's natural jaw movements, improving longevity and patient comfort. For instance, a crown designed with Modjaw data ensures optimal contact points, reducing the need for post-placement adjustments.

Orthodontic treatments rely on understanding how teeth move in relation to jaw dynamics. Modjaw provides insights into how tooth alignment affects mandibular function, enabling orthodontists to plan treatments that optimize both aesthetics and functionality. This is particularly valuable in complex cases, such as open bites or crossbites, where jaw movement plays a significant role.

For patients requiring dentures or implant-supported prostheses, Modjaw ensures that the prosthetic design aligns with the patient's natural jaw motion. This reduces the risk of discomfort, instability, or excessive wear on the prosthesis. The system's ability to simulate chewing patterns also aids in creating prosthetics that mimic natural function.

Modjaw is also a valuable tool for dental researchers studying jaw biomechanics, occlusion, and related pathologies. Its data can be used to model jaw behavior under different conditions, contributing to advancements in dental science. Additionally, dental schools use Modjaw to train students in dynamic occlusion analysis, preparing them for modern clinical practice.

ADVANTAGES OF MODJAW OVER TRADITIONAL METHODS

Compared to conventional articulators and diagnostic tools, Modjaw offers several advantages. Real-time motion capture provides more precise data than static models. The system uses lightweight markers and scanners, ensuring patient comfort. Modjaw integrates seamlessly with CAD/CAM systems, streamlining treatment planning and fabrication. Patient-specific data enables tailored interventions, improving outcomes. By reducing the need for manual adjustments, Modjaw saves time for clinicians and patients.

However, Modjaw is not without challenges. The system requires an initial investment in equipment and training, which may be a barrier for smaller practices. Additionally, the technology relies on high-quality intraoral and facial scans, which can be affected by patient cooperation or scanning errors. Despite these limitations, the benefits of Modjaw make it a transformative tool in modern dentistry.

Fig. 2 Real-time motion capture

DISCUSSION

The integration of jaw morphodynamics into modern dental diagnostics represents a profound shift in how functional anatomy is evaluated and understood. Traditional diagnostic paradigms, largely based on static records such as dental casts, two-dimensional radiographs, and snapshot occlusal assessments, offer limited insight into the dynamic, real-world function of the mandible. These methods inherently assume a static relationship between anatomical structures, which does not reflect the continuous motion and variability inherent in natural oral activities such as chewing, speaking, and swallowing. As dental practice evolves toward greater precision and personalization, the demand for a dynamic, functionally integrated diagnostic model becomes imperative.4,5

Jaw morphodynamics defined as the study of mandibular movement in three-dimensional space over time has long been recognized as a critical component of temporomandibular function and occlusal health. However, the ability to measure and analyze these movements in a clinically meaningful and reproducible manner has remained elusive until recent technological advances. This is where Modjaw technology serves as a turning point. It offers real-time, four-dimensional (4D) motion capture of the mandible, allowing clinicians to visualize and quantify mandibular kinetics with unprecedented accuracy.3,6

The core value of Modjaw lies in its ability to provide a true-to-life representation of mandibular function, captured in a natural, unforced state. Unlike traditional jaw tracking systems that often rely on mechanical attachments or restrict head movement, Modjaw's non-invasive optical tracking and integration with digital intraoral scans allow for a more natural depiction of functional movements. This real-time acquisition and synchronization of mandibular motion with dental arches bring forth a new level of diagnostic precision, enabling a clearer differentiation between normal and pathological patterns.7,11

From a clinical perspective, the significance of this dynamic approach cannot be overstated. Disorders of the temporomandibular joint (TMJ), occlusal discrepancies, neuromuscular imbalances, and adaptive postural changes often manifest subtly through altered mandibular movements long before radiographic or anatomical signs become apparent. By capturing functional data such as incisal and condylar paths, lateral excursions, and opening-closing trajectories, Modjaw provides actionable insights that were previously obscured in static models. This allows for earlier detection of dysfunction, more precise identification of the etiologic factors, and more targeted therapeutic interventions.9,16

Moreover, this dynamic data acquisition paves the way for functional diagnostics to be incorporated seamlessly into the broader digital dentistry workflow. By linking Modjaw's 4D recordings with digital impressions and 3D facial scans, clinicians can construct a comprehensive, anatomically and functionally accurate digital twin of the patient.8 This digital twin is not just a visualization tool it becomes a functional simulation environment where prosthetic restorations, orthodontic plans, or surgical interventions can be tested and refined based on real-world jaw function. It bridges the gap between diagnosis and treatment planning by ensuring that

any restorative or corrective work is harmonized with the patient's functional envelope.14,15
However, the integration of jaw morphodynamics into routine clinical practice also raises important conceptual and practical challenges. Clinicians must now shift from interpreting static anatomic relationships to analyzing complex, temporally dynamic data.16 This requires new interpretive frameworks, educational resources, and software tools capable of distilling large datasets into clinically meaningful insights. The learning curve associated with interpreting kinematic patterns such as irregular condylar hinge movements, phase lags between jaw segments, or non-symmetrical excursions must be addressed through continued professional development and incorporation of these principles into dental curricula.17,18

Another area warranting attention is the standardization of diagnostic thresholds and interpretation protocols. Unlike traditional static parameters, for which normative values and clinical benchmarks have been well established, dynamic mandibular data is still in its relative infancy in terms of normative databases and consensus interpretation. There is a risk that variability in data acquisition techniques, patient compliance, and clinician interpretation may lead to inconsistencies in diagnosis unless carefully controlled. Future research and collaboration across institutions will be necessary to define standard ranges of motion, velocity profiles, and condylar paths for different demographics, pathologies, and occlusal morphologies.9

Additionally, jaw morphodynamics as assessed through Modjaw opens new investigative pathways in understanding the interplay between craniofacial morphology, muscular coordination, and occlusion. It presents an opportunity to redefine the clinical significance of concepts such as centric relation, occlusal guidance, and neuromuscular balance. For instance, discrepancies between static occlusal contacts and dynamic functional trajectories may reveal maladaptive compensations that are not clinically evident in traditional records. Such insights could reshape treatment goals in prosthodontics, orthodontics, and TMD therapy, emphasizing functionally integrated solutions over merely anatomical alignment.
Furthermore, this technology challenges the traditional compartmentalization of dental disciplines. Functional analysis of the mandible is not solely the concern of TMD specialists or prosthodontists; it has profound implications for implant placement, orthodontic movement, restorative design, and even airway assessment. A dynamic diagnostic tool like Modjaw encourages interdisciplinary collaboration, where insights from one specialty enhance the precision and effectiveness of interventions in another.3,17

Despite the clear potential of jaw morphodynamics and Modjaw in revolutionizing diagnostic paradigms, it is crucial to maintain a critical perspective. The adoption of new technology must be grounded in evidence-based protocols and accompanied by rigorous clinical validation. Ongoing studies are required to establish the sensitivity, specificity, and predictive value of Modjaw data in various diagnostic contexts. Moreover, the ethical implications of data storage, patient privacy, and informed consent in the context of motion capture and digital modeling must be carefully addressed.

FUTURE IMPLICATIONS OF MODJAW AND JAW MORPHODYNAMICS

The integration of technologies like Modjaw into dental practice signals a shift toward precision dentistry. As digital tools become more accessible, we can expect broader adoption of dynamic jaw analysis in routine care. Future advancements may include artificial intelligence (AI) integration, allowing AI algorithms to analyze Modjaw data to predict treatment outcomes or identify early signs of pathology. Modjaw's digital models could also be shared remotely, enabling consultations with specialists worldwide through tele-dentistry applications.

Interactive visualizations of jaw dynamics could help patients understand their conditions and treatment plans, improving patient education. Additionally, Modjaw data could be used by maxillofacial surgeons, orthodontists, and physical therapists to coordinate care for complex cases, fostering interdisciplinary collaboration.9,22

Ongoing research into jaw morphodynamics could uncover new insights into craniofacial development, aging, and disease progression. By combining biomechanical data with genetic and environmental factors, scientists may develop novel therapies for conditions like TMD or sleep apnea. In conclusion, Modjaw represents a significant advancement in dental diagnostics, merging real-time jaw tracking with digital imaging to enhance diagnosis, treatment planning, and patient outcomes.21

SUMMARY

Jaw morphodynamics refers to the study of dynamic jaw movements and their interaction with anatomical structures like the temporomandibular joint (TMJ), maxilla, mandible, and masticatory muscles. Accurate analysis of these movements is essential for diagnosing disorders and customizing dental treatments.Traditional diagnostic tools, such as mechanical articulators and static imaging, fall short in capturing the complexity of real-time mandibular function. Modjaw addresses this limitation by offering a non-invasive, high-resolution, 4D jaw tracking system. It combines intraoral and facial scans with infrared motion capture to create a digital twin of the patient's jaw, enabling the visualization of jaw dynamics during functional activities such as chewing and speaking.This technology significantly enhances clinical decision-making across multiple dental disciplines. In TMD management, Modjaw helps identify dysfunctional movement patterns. In restorative and prosthetic dentistry, it ensures occlusal harmony and reduces post-treatment adjustments. Orthodontists can use Modjaw to align treatments with natural jaw behavior, while implantologists benefit from prosthetics that replicate true function. Additionally, it offers value in education and research by enabling detailed analysis of jaw biomechanics.2

Despite the initial investment and learning curve, Modjaw's integration with CAD/CAM workflows, its precision, and patient-specific capabilities make it a transformative tool in modern dentistry. The article concludes by highlighting the future potential of combining Modjaw with AI and tele-dentistry, which could further enhance diagnostic accuracy, patient education, and interdisciplinary collaboration.

CONCLUSION

Jaw morphodynamics, with its focus on the interplay between form and function, is a critical field in modern dentistry. The advent of Modjaw technology has revolutionized how clinicians' study and treat jaw-related conditions, offering unprecedented precision and customization. From diagnosing TMD to designing patient-specific restorations, Modjaw enhances clinical outcomes while streamlining workflows. As the technology evolves, it promises to further transform dental care, making it more accurate, efficient, and patient-centered. By embracing tools like Modjaw, the dental profession is poised to unlock new frontiers in understanding and optimizing jaw function.

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Review Article

Various Treatment Modalities for Oral Submucous Fibrosis: A Review

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Abstract:
Oral Submucous Fibrosis (OSMF) is a chronic and precancerous condition that affects the oral mucosa, oropharynx, and occasionally the larynx. It is a progressive condition that is poorly understood and has limited treatment options. Conventional treatments for OSMF mainly focus on providing symptomatic relief. This article reviews the literature on alternative medicine therapies, such as physiotherapy, Ayurveda, and homeopathy, for treating OSMF. These alternative modalities offer a natural and cost-effective treatment option. Incorporating these therapies into lifestyle modifications may contribute to the cure of the disease. However, further research, including relevant randomized control trials, is necessary to increase awareness and encourage patients to consider these non-invasive therapeutic options as a primary treatment approach.

Keywords- OSMF, Allied, Treatment, Alternative

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INTRODUCTION

Oral submucous fibrosis (OSMF) is a pre-malignant chronic condition that have effect on oral region and pharyngeal region. t is characterized by juxtaepithelial inflammatory reaction & by fibrous and elastic changes of the lamina propria, leading to tightness of the oral mucosa, difficulty in mouth opening, and difficulty in eating (1). It is a progressive condition and is poorly understood and treated. Areca nut chewing is a primary cause of OSMF, along with other factors such as poor nutrition, spicy food intake, inheritance, autoimmune, and collagen fibres disease (2). This disorder which is most common in India, is an indicator of oral cancer with a prevalence of about 0.4% in village areas, after that Bangladesh, Sri Lanka, Pakistan, Taiwan, and China. In India, OSMF is prevalent in Bihar, Maharashtra, Gujarat, and Madhya Pradesh(3). Management options for OSMF include steroids, hyaluronidase, placenta extract, IFN, microwave diathermy, and non-conservative interventions like excision of fibrotic tissues and grafting(4). Together with these treatment modalities, scientific research indicates that additional allied therapies such as Ayurvedic preparations, Homeopathy, and Physiotherapy provides a relatively safer, more economical, and effective complementary approach along with current conventional treatment, which can be particularly advantageous in India. The publication briefly examines causes of the serious disease, along with a results of previous studies conducted in different allied medical fields as potential treatments for OSMF.

DISCUSSION

The development of Oral submucous fibrosis is considered to have a multivariate etiopathogenesis, with the condition being known as a collagen metabolic disorder. Chewing betel quid is recognized as the most significant risk factor. The flowchart below illustrates the pathogenesis of OSMF following the consumption of arecanut [5]. (Figure 1 and 2a, 2b).

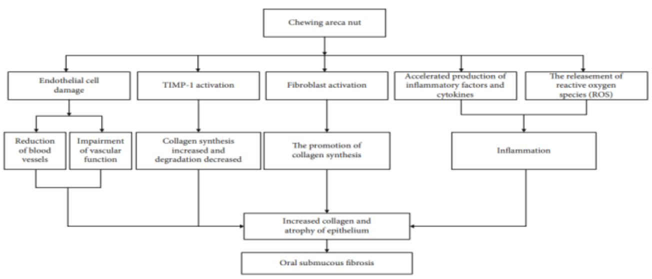

FIGURE 1: The etiopathogenesis of OSMF caused by chewing areca nut.

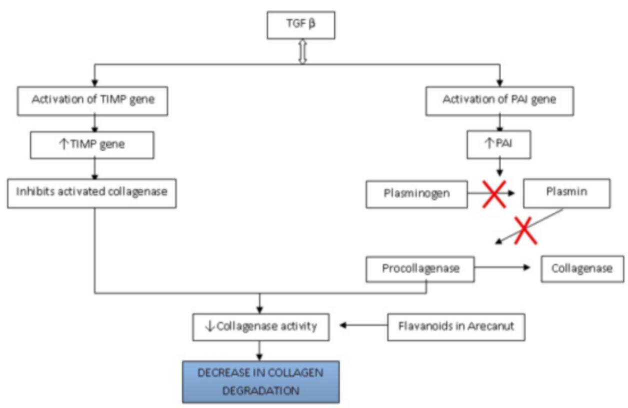

Figure 2a: *Flowchart explaining the decrease in collagen degradation which increases the risk of OSMF.*

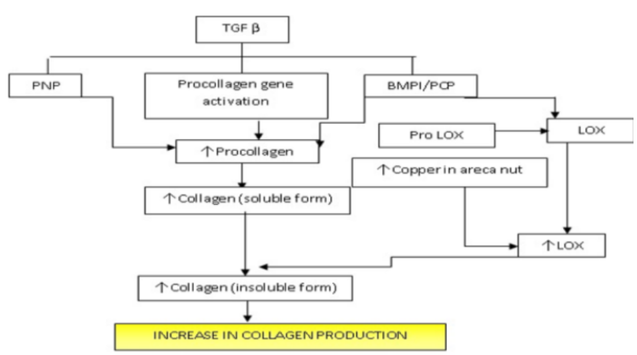

Figure 2b: *Flowchart explaining the increase in collagen production which increases the risk of OSMF.*

Long-term relief can be achieved by directing treatment modalities towards controlling the reactions that take place during the pathogenesis of the disorder, instead of just addressing the symptoms. Numerous allied medicine therapies are currently aimed at intervening in this cascade of events. The current choices for treatment only provide short-term symptom alleviation. Consequently, studies are being carried out to look into complementary medicines for treating OSMF or as a useful adjuvant for symptom relief.

MEDICINAL TREATEMENT

The management of OSMF embraces a holistic perspective for allied medicine. Scientific literature has identified various allied medicine therapies that have shown positive results in addressing OSMF.

Ayurveda
Turmeric

Turmeric, also referred to as Curcuma longa Linn, converted to a bright yellowish powder is characterized by slightly bitter but sweet taste profile(6). This spice is celebrated for its wide range of therapeutic benefits, which contains properties that prevent inflammation(7), and oxidation(8), enhances blood flow(9), in addition potentially prevents genetic mutations(10).

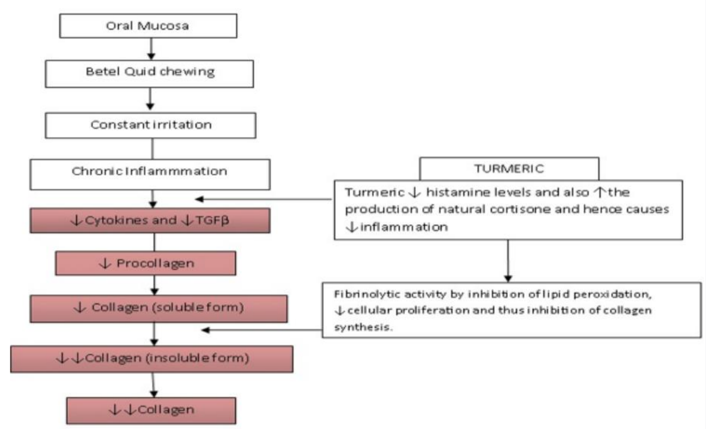

Figure 3: Flowchart explains the action of turmeric in decreasing histamine levels to decrease information and decrease in coolagen production.

Curcumin, specifically, prevents inflammation and agents that hinders the progression of certain diseases by interfering with specific cellular processes. It's remarkable anti-inflammatory characteristic makes it potent mediator that suppresses cell conversion, multiplication, and metastasis. By inhibiting Tumour necrosis factor-made

Nuclear factor-κappa- light-chain enhancer of activated B cells stimulation and Nuclear factor-κappa- light-chain enhancer of activated B cells -reliant reporter gene expression [11], curcumin effectively targets the site of action for treating OSMF, as depicted in Figure 3.

In vitro research of Hastak et al. reveals the combination of turmeric oil and turmeric oleoresin offers a synergistic effect, effectively safeguarding against DNA damage. This discovery highlights the promising role of curcumin in the management of OSMF.

Holy Basil

In Ayurvedic litreature, it is advised for improving immunity and metabolic functions, while also helping to decrease inflammation by inhibiting enzymes that cause inflammation (13). A research demonstrated that, combination using turmeric & holy basil is highly effective in treating OSMF, leading to early relief from burning and improved mouth opening, especially in severe cases (14).

Gwar Patha

Gwar Patha is recognized for its soothing properties due to the presence of a non-filamentous glycoprotein consisting of various amino acids referred to as 'wound healing hormones'(15). Its leaf contains polysaccharides that offer prevention of inflammatiom, immunity modulation, prevent oxidation, and wound-healing benefits. Moreover, Gwar Patha is known for prevention of bacterial, viral, fungal infections & its antiseptic, hypoglycemic properties, along with its ability to enhance the immune system (16,17). By promoting blood flow, Gwar Patha aids in wound healing by increasing oxygen supply. Its soothing and cooling effects help alleviate pain and burning sensations in individuals with OSMF (18).

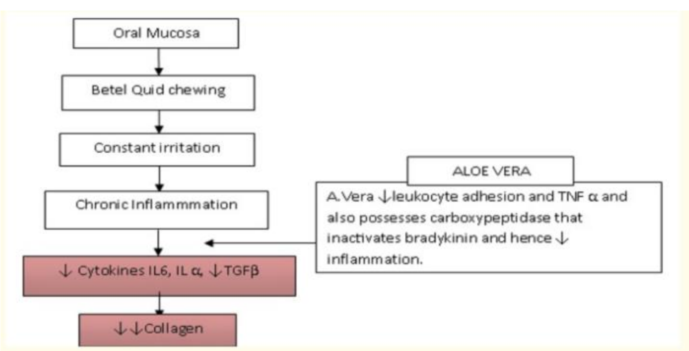

***Figure 4:** Flowchart explains action of Aloe Vera causing decreasing in leukocyte adhesion and inactivation of bradykinin thus causing drecrease in inflammation.*

Alam S. et al. looked at effectiveness of Gwar Patha ointment as an alternative for OSMF and found groups that received Gwar Patha significantly improved in most OSMF symptoms[15]. In some research, Group A received pure Gwar Patha gel while Group B received pure Gwar Patha juice, both experiencing a notable reduction in burning sensation. Group A showed a rapid reduction, whereas Group B had a more gradual improvement [19]. Different research reported that Gwar Patha not only minimize burning sensation but also improved cheek flexibility [20]. It is essential to monitor the use of Gwar Patha carefully, especially during pregnancy, as it may lead to uterus contractions and GIT disturbance. Furthermore, mouth intake of Gwar Patha may cause pain in abdomen and reduce potassium in the body [21,22].

Oxitard

Various clinical trials have assessed the efficacy of Oxitard, a natural antioxidant, as a supportive therapy for OSMF. A research led by Patil S., et al. revealed potential improvements in opening of mouth, movements of tongue, burning sensation, pain related to the lesion, deglutition challenges, and speech among patients with OSMF who were treated with oxitard capsules [23].

Spirulina

With its abundance of proteins, carotenoids, and other micronutrients, Spirulina serves as an exceptional nutritional source. Furthermore, its potent antioxidant capabilities, stemming from its high concentration of B-carotene and superoxide dismutase, make it an better treatment (24).

Physiotherapy

OSMF presents with early signs characterized by the whitening of the mouth & formation of fibrous bands in specific areas like the cheek mucosa, hard & soft palate, laryngeal region, lips, and tongue. The primary manifestation of OSMF is the difficulty in opening the mouth. To address the reduction in tissue elasticity, many studies have investigated it as an additional management modality.

Kneading: Method for enhancing the springiness of fibrous tissues and facilitate the mobilization of scar tissues. Soft tissue manipulation is a key component for improving tissue stretchability (25).

Muscular Activity: To avoid other restrictions in oral functions and avoid relapse, muscle stretching activities can beneficial. Methods like utilizing a mouth blocks, acrylic surgical stent, mouth bloating, warm rinse with water, inserting a ice cream stick between the teeth, and gradually adding a new ice cream sticks every 5 - 10 days can be employed (26).

Utilization of Heat: Using heat, whether it be through hot gargles, or specific deep heating techniques like small wave or micro wave diathermy, is a technique employed to address trismus resulting from OSMF (26).

Ultrasound Equipment (Electroson) and Cryotherapy
Vijayakumar M. et al. conducted a study aimed at enhancing oral opening and tongue movements in OSMF cases. Different activities were implemented for research part. All patients received treatment using the same ultrasound equipment, followed by finger & thumb kneading within the buccal region of the oral region. This technique involved gently stretching the fibrous bands within tolerable pain limits. Cryotherapy was administered before and after the treatment for a duration of 5-7 minutes to minimize pain sensation. The researchers also performed kind stretch on the buccal region using their fingers. To improve jaw depression, temporo-mandibular joint mobilization was conducted through Antero-inferior glides, while lateral glides were employed to enhance mandible deviation along with joint distraction. The research yielded positive results, with average enhancement in oral opening & significant enhancement in tongue movements (27).

Undoubtedly, the implementation of physiotherapy involvements in the early grades of OSMF leads to great enhancement in the individual's health, while ensuring a complete absence of side effects. Consequently, these interventions can be adopted as management practise for OSMF patients, serving as a non-aggressive alternative to non-conservative interventions.

Homeopathy
Recent scientific literature highlights a shift towards homeopathy as a preferred choice over allopathy for managing medical conditions. Homeopathy is valued for its holistic approach to health, focusing on overall well-being rather than just treating specific diseases. While it cannot replace traditional dentistry, homeopathy can be used in conjunction with conventional dental treatments (28). Research supports the use of homeopathic science in dental practise, particularly for conditions like trismus. Homeopathic remedies such as Calcarea phosphorica and Cuprum metallicum are effective in addressing trismus and other dental issues with minimal side effects and positive treatment outcomes. Homeopathy has become an important complementary therapy in cases where conventional drugs have not yielded satisfactory results. More investigation is required to fully appreciate the benefits of homeopathic treatment for conditions like OSMF (29).

CONCLUSION

The treatment options discussed in this context provide a natural and affordable approach to treatment. Their healing properties, originating from natural sources, can be effectively harnessed. OSMF is a premalignant condition with a complex set of causes, and no single standard treatment has been definitively successful. While existing research supports positive outcomes of complementary therapies in managing OSMF, there is a need for more evidence to establish them as a definitive treatment option. Therefore, it is crucial to conduct appropriate randomized controlled trials to raise awareness and promote their use as chief non-aggressive therapeutic approach.

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Review Article

Advances in Bone Augmentation: Enhancing Implant Success in Modern Dentistry

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Abstract:
Bone augmentation is a crucial procedure in implant dentistry, addressing deficiencies in alveolar bone volume to ensure successful implant placement. Various techniques have been developed to enhance bone regeneration, including autogenous bone grafts, allografts, xenografts, guided bone regeneration (GBR), and biomaterial-based approaches.**Objective:** This review explores recent advancements in bone augmentation techniques and their clinical applications, providing a comparative analysis of success rates, complications, and future prospects.**Methods:** A comprehensive literature search was conducted to identify recent advances in bone augmentation techniques for implant placement. Electronic databases, including **PubMed**, **Cochrane Library**, **ScienceDirect**, and **Wiley Online Library**, were searched for relevant articles . It includes articles published between **1986 and 2021**, covering approximately **35 years** of research on bone augmentation for implant placement.**Results:** Emerging technologies, including 3D printing, bioactive molecules, and stem cell therapies, have demonstrated promising results in enhancing bone regeneration. Additionally, digital workflows such as computer-assisted planning and cone beam computed tomography (CBCT) have improved precision in graft placement. Despite advancements, challenges such as donor site morbidity, cost, and prolonged healing remain. **Conclusion:** Continuous innovations in biomaterials and surgical techniques are transforming bone augmentation, improving implant success rates and patient outcomes. Future research should focus on personalized regenerative approaches and artificial intelligence-assisted treatment planning to further optimize implantology procedures.

Keywords- Bone augmentation, dental implants, guided bone regeneration, bone grafts, 3D printing, stem cell therapy

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INTRODUCTION

Dental implants are essential for restoring function, aesthetics, and oral health in patients with missing teeth. They prevent bone resorption by stimulating the jawbone, maintaining facial structure, and improving mastication and speech1. Unlike traditional dentures or bridges, implants offer a long-term solution without compromising adjacent teeth2. They enhance patient comfort, reduce the risk of further tooth loss, and provide a natural-looking smile3. With high success rates and continuous advancements in materials and techniques, dental implants remain the gold standard for tooth replacement, significantly improving patients' quality of life4.

One of the most important prerequisites for successful implant placement is the presence of adequate bone volume. Without sufficient bone support, implants may fail due to poor osseointegration and lack of stability5. Bone deficiency occurs due to various factors, including tooth loss, periodontal disease, trauma, infection, and congenital defects6. After tooth extraction, the alveolar bone undergoes resorption due to the lack of functional stimulation, leading to reduced bone height and width7. Additionally, prolonged edentulism results in progressive bone atrophy, making implant placement challenging8. Understanding these causes highlights the importance of bone augmentation to restore lost bone and ensure successful implant integration9.

Successful implant placement requires sufficient bone volume for stability and osseointegration. Bone augmentation is a critical procedure to restore lost bone volume and provide a stable foundation for implant placement10. It is required when natural bone is insufficient due to resorption, trauma, or pathology11. Bone grafting materials and techniques have been developed to address these challenges, with ongoing research focused on improving clinical outcomes12. This review aims to examine the latest advancements in bone augmentation and their impact on implant dentistry.

BONE GRAFT MATERIALS

Bone graft materials in implant dentistry are classified into four main categories: autografts, allografts, xenografts, and alloplasts, each with distinct properties influencing their clinical application.

Autografts

These are considered the gold standard, are harvested from the patient's own body, typically from the iliac crest, chin, or mandibular ramus13. These grafts possess osteogenic, osteoinductive, and osteoconductive properties, making them highly effective for bone regeneration. However, they require an additional surgical site, leading to increased morbidity and limited availability[5].

Allografts

These are derived from human cadaveric sources and processed in tissue banks, provide an alternative without the need for a secondary surgical site. They come in various forms such as fresh-frozen bone (FFB), freeze-dried bone allograft (FDBA), and demineralized freeze-dried bone allograft (DFDBA), with the latter being rich in bone morphogenetic proteins (BMPs) that enhance osteoinduction14. While allografts eliminate donor site morbidity, they lack viable osteogenic cells and have a lower regenerative potential compared to autografts[8].

Xenografts

Xenografts are obtained from non-human species such as bovine, porcine, or equine sources, serve as osteoconductive scaffolds that support bone regeneration. These materials, including bovine-derived hydroxyapatite (Bio-Oss), are biocompatible and provide long-term volume stability due to their slow resorption rate7. However, they lack osteogenic potential and may integrate more slowly with the host bone[12].

Alloplasts

These are synthetic bone substitutes like hydroxyapatite (HA), beta-tricalcium phosphate (β-TCP), bioactive glass, and calcium sulfate, offer a versatile and unlimited supply of grafting material. These biomaterials vary in their resorption rates and osteoconductive properties, with bioactive glass stimulating osteogenesis through the formation of a direct bond with natural bone15. While alloplasts eliminate the risk of disease transmission and can be customized to fit defect shapes, they generally lack the osteoinductive and osteogenic capabilities found in autografts[11].

The choice of bone graft material depends on several factors, including the extent of bone deficiency, anatomical location, patient-specific considerations, and clinician preference. While autografts remain the most effective due to their superior biological properties, allografts, xenografts, and alloplasts serve as valuable alternatives with varying degrees of efficacy[6].

BONE AUGMENTATION TECHNIQUES IN IMPLANT DENTISTRY

Bone augmentation techniques play a crucial role in implant dentistry by compensating for insufficient bone volume and ensuring the stability and longevity of dental implants. Various techniques are employed based on the severity and location of bone deficiency. Below are the most commonly used methods:

Guided Bone Regeneration (GBR)
Guided Bone Regeneration (GBR) is one of the most widely used techniques to enhance bone volume before or during implant placement. This method involves placing a resorbable (collagen-based) or non-resorbable (PTFE) barrier membrane over a bone graft to prevent soft tissue infiltration, allowing undisturbed bone regeneration. GBR is particularly effective in horizontal ridge augmentation and small to moderate defects[16].

Sinus Augmentation (Sinus Lift)
Sinus augmentation is necessary when the posterior maxilla lacks sufficient bone height due to pneumatization of the maxillary sinus or bone resorption following tooth loss. The procedure involves lifting the Schneiderian membrane and filling the space with bone graft material. It can be performed via the lateral window approach, which provides direct access to the sinus floor, or the crestal (internal osteotome) approach, which is less invasive and used for minor augmentations[17].

Ridge Augmentation (Horizontal and Vertical Augmentation)
Ridge augmentation is performed when the alveolar ridge is too narrow or short to support an implant. Horizontal augmentation is used to increase ridge width, while vertical augmentation restores bone height. These techniques involve using autogenous block grafts, particulate bone grafts, titanium-reinforced membranes, or titanium mesh to create space for new bone formation. Ridge augmentation is often combined with GBR for enhanced outcomes6.

Distraction Osteogenesis (DO)
Distraction osteogenesis is a surgical technique used to increase vertical bone height without grafting materials. The procedure involves making a controlled osteotomy and gradually separating the bone segments using a distraction device. This controlled movement stimulates new bone formation in the gap. Although highly effective for severe vertical deficiencies, it requires a longer healing period compared to other techniques[18].

Use of Growth Factors and Platelet Concentrates
Advancements in regenerative medicine have introduced biological enhancers such as Bone Morphogenetic Proteins (BMPs), Platelet-Rich Plasma (PRP), and Platelet-Rich Fibrin (PRF) to improve bone augmentation outcomes. These factors accelerate bone healing and enhance the integration of graft materials, leading to faster recovery and higher implant success rates[19].

Titanium Mesh
Titanium mesh is a non-resorbable, biocompatible material used in guided bone regeneration (GBR) to support bone grafts and maintain space for new bone formation. It provides mechanical stability, prevents soft tissue collapse, and is adaptable to various bone defects, making it effective for horizontal and vertical ridge augmentation[20]. Despite its advantages, complications like soft tissue exposure and infection can occur, necessitating careful surgical handling[21].

RECENT ADVANCES IN BONE AUGMENTATION FOR IMPLANT PLACEMENT

3D Printing & Custom Grafts
The introduction of 3D bioprinting has revolutionized bone augmentation by enabling patient-specific scaffold fabrication with enhanced precision and defect adaptation. These scaffolds, made from calcium phosphate-based bioceramics and polymer-based composites, exhibit improved osteoconductivity and mechanical strength22. Additionally, bioengineered 3D-printed grafts loaded with growth factors or stem cells have demonstrated superior bone regeneration potential in preclinical and clinical studies[23].

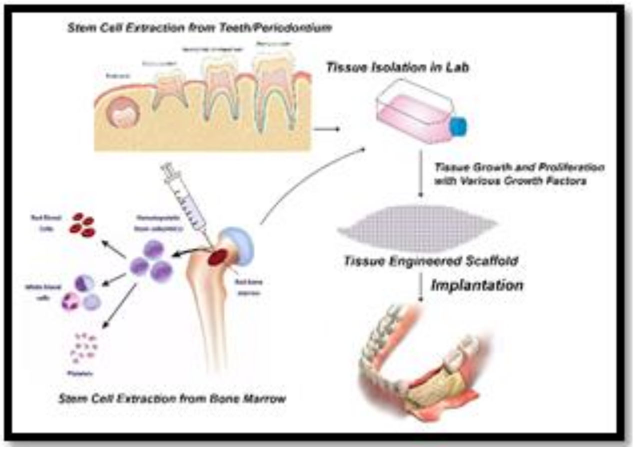
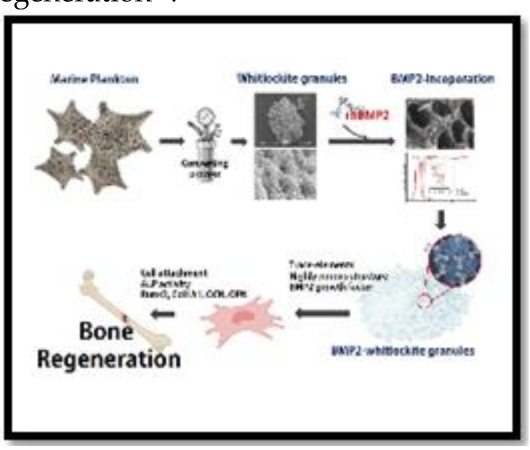


Fig1: Tissue engineered scaffold for implant

Growth Factors & Stem Cell Therapy

Biologically active molecules such as bone morphogenetic proteins (BMPs), platelet-rich fibrin (PRF), and platelet-rich plasma (PRP) have shown promising results in enhancing osteogenesis and accelerating the healing process24. Combining these biomaterials with scaffolds improves their regenerative potential and integration with host tissues. Mesenchymal stem cells (MSCs), either autologous or allogeneic, are being extensively studied for their ability to differentiate into osteoblasts and promote bone formation25. Emerging research in genetically modified stem cells and exosome-based therapies is also opening new possibilities for targeted bone regeneration[26].



Minimally Invasive Techniques

Advancements in piezoelectric surgery and ultrasonic methods have enabled more precise bone cutting with minimal trauma to surrounding tissues, leading to reduced surgical morbidity and improved healing27. Additionally, minimally invasive tunneling techniques have been developed for bone graft placement, reducing postoperative discomfort and lowering the risk of complications28.

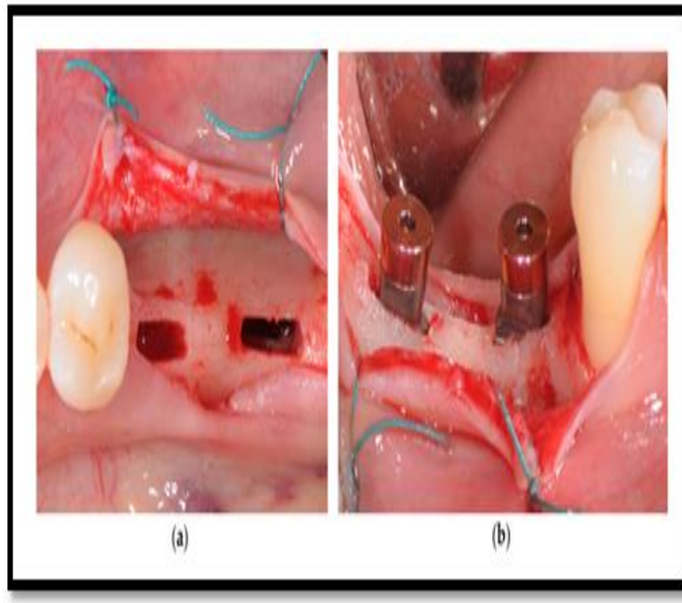


Fig3: (a) Implant site preparation performed with piezoelectric tips; (b) Implant seating in the final position

Computer-Assisted Planning & Navigation Systems

Digital technologies such as cone beam computed tomography (CBCT) and virtual surgical planning allow for highly accurate graft placement and implant positioning, improving surgical predictability[29]. Artificial intelligence (AI) is being integrated into treatment planning, where CBCT-based predictive models help assess bone density, volume, and potential complications30. Furthermore, robotic-assisted surgery is under investigation for optimizing precision in bone augmentation procedures[31].

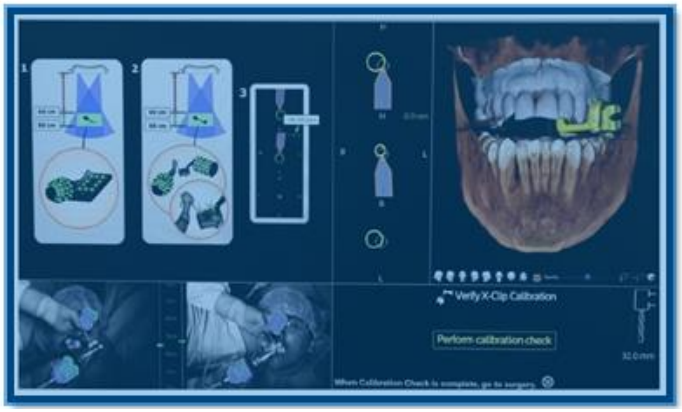


Fig4: Surgical calibration prior to surgery for implant

Bioactive and Smart Biomaterials
Innovations in bioactive materials, such as bioactive glass and osteoinductive hydrogels, have led to faster bone regeneration by enhancing cellular response and mineralization32. Smart biomaterials that can release growth factors in a controlled manner or respond to biological cues are being developed to improve healing outcomes and minimize complications[33].

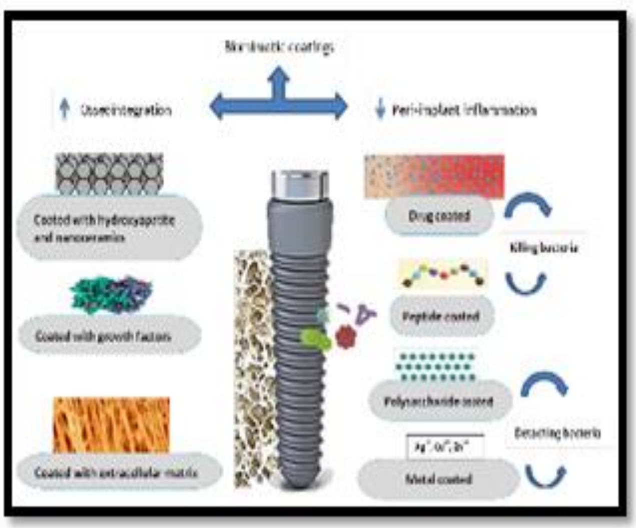


Fig5: Various coatings of biomimetic material for implant

Gene Therapy & Molecular Approaches
Gene therapy has emerged as a novel approach to enhance bone regeneration through the targeted delivery of osteogenic genes such as BMP-2 and Runx234. Researchers are exploring viral and non-viral gene delivery systems to improve the efficiency and safety of gene therapy in bone augmentation. Additionally, molecular signaling pathways, including Wnt and Notch, are being investigated to develop pharmacological agents that stimulate osteogenesis and improve graft survival35.

Clinical Outcomes & Comparisons
Success rates of different techniques vary based on patient-specific factors, graft material selection, and surgical protocol. Long-term stability assessments indicate that autogenous grafts maintain volume better, whereas allografts and xenografts require prolonged remodeling periods. Complication rates such as infection, graft failure, and resorption are minimized with advancements in material science and surgical techniques.

Limitations & Future Directions
Challenges such as cost, healing time, and patient-specific factors continue to affect clinical decision-making. Research into biomimetic materials and tissue engineering approaches aims to develop superior alternatives for bone regeneration. The integration of artificial intelligence in treatment planning and automated graft fabrication could revolutionize personalized patient care in the near future.

CONCLUSION

Bone augmentation has revolutionized implant dentistry, providing solutions for patients with insufficient bone volume to achieve successful implant placement. With advancements in biomaterials, growth factors, and digital technologies, modern bone regeneration techniques have significantly improved clinical outcomes, reducing morbidity and enhancing predictability. The integration of 3D printing, smart biomaterials, and gene therapy offers promising avenues for personalized and accelerated bone healing. As research continues to refine these techniques, the future of implant dentistry is poised for even greater innovation, ensuring optimal patient care and long-term success in oral rehabilitation.

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Review Article

Precision Medicine in Periodontics: A Literature Review

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Abstract:
Periodontitis remains a globally prevalent chronic inflammatory disease with profound public health implications. Its rising incidence and adverse social consequences necessitate innovative preventive and therapeutic strategies. Beyond its local impact, periodontitis is increasingly recognized for its role in exacerbating systemic health disorders, underscoring the urgency for more refined management approaches. Conventional diagnostic tools such as probing depth, clinical attachment level, tooth mobility, and radiographic evaluation of alveolar bone offer limited predictive value and therapeutic guidance due to the complex and multifactorial nature of periodontal diseases. Precision periodontics, integrating advances in genomics, bioinformatics, and patient-specific biomarkers, aims to shift care toward personalized treatment paradigms. Despite its promise, the clinical application of this model in periodontology is still in its nascent stages, mainly due to the paucity of clinically validated biomarkers. This article critically examines the evolving role of personalized diagnostics in periodontics and evaluates the current and prospects of biomarker-driven precision care in managing periodontal disease.

Keywords: Precision periodontics, patient-specific biomarkers, biomarkers, biomarker-based diagnostics, periodontitis.

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INTRODUCTION:

Periodontitis is a major global health burden, ranked as the 11th most prevalent disease worldwide according to the Global Burden of Disease Study (2016) [1]. Severe forms affect approximately 20% to 50% of the population, significantly contributing to tooth loss, which impairs oral function, facial aesthetics, self-esteem, and overall quality of life [2]. These consequences have driven a global emphasis on enhancing preventive and therapeutic measures to improve diagnostic accuracy, clinical outcomes, and reduce the financial strain of periodontal treatment.

At the core of periodontal disease lies the complex interaction between dysbiotic microbial communities in dental plaque and the host's dysregulated immune-inflammatory response [3]. Effective treatment thus necessitates disruption of the pathogenic biofilm. Given the multifactorial nature of periodontitis, biomarker-based diagnostics offer promising advantages over traditional clinical and radiographic assessments. Biomarkers allow for individualized risk assessment, early detection, prognosis, and tailored therapeutic interventions that better align with each patient's unique biological profile [4].

In vitro diagnostics (IVDs), already influential in guiding more than 60% of medical decisions, are increasingly being explored in dentistry as tools for enhancing diagnostic precision and therapeutic efficacy. The 2017 classification of periodontal and peri-implant diseases marked a pivotal moment with the inclusion of biomarkers, setting the foundation for integrating precision medicine into periodontology [5]. Precision medicine, an approach that personalizes care based on a combination of genetic, molecular, phenotypic, and psychosocial characteristics, is now transforming multiple medical disciplines. However, its integration into periodontal practice remains limited, primarily due to the absence of thoroughly validated diagnostic biomarkers.

LIMITATIONS AND COMPLEXITIES OF CONVENTIONAL APPROACHES

Traditional diagnostic modalities in periodontology chiefly clinical probing and radiographic evaluation primarily assess parameters such as clinical attachment loss, probing depth, and alveolar bone resorption. While these measures provide historical insights into periodontal tissue destruction, they fall short in detecting ongoing disease activity or predicting future progression [6]. Additionally, individual variability in genetic susceptibility and temporal disease expression poses further diagnostic challenges, making it difficult to apply a one-size- fits-all diagnostic approach.

Recent developments in biomedical sciences, particularly in high-throughput omics technologies, advanced diagnostic platforms, and artificial intelligence, have exposed the deficiencies of conventional diagnostic strategies in managing periodontal diseases [7]. The keystone pathogen hypothesis has significantly reshaped our understanding of the microbial etiology of periodontitis, particularly with the identification of Porphyromonasgingivalis as a key pathogen capable of orchestrating dysbiosis within the subgingival microbiome [8,9]. Rather than being a simple result of pathogenic colonization, periodontitis is now viewed as the outcome of a complex interplay between a dysbiotic microbial community and the host's aberrant inflammatory response [10,11].

This paradigm shift highlights the importance of evaluating not only the microbial composition but also host immune responses and other contributing risk factors. Environmental influences, systemic health conditions, genetic polymorphisms, and even viral or fungal coinfections can all compromise host defences. Individuals with hyper-responsive or genetically predisposed immune systems are particularly vulnerable to aggressive and refractory forms of periodontal disease [12]. Consequently, conventional clinical and radiographic tools, which offer limited insight into such multifactorial mechanisms, are increasingly seen as inadequate for comprehensive diagnosis and personalized treatment planning. The integration of biomarkers into diagnostic workflows offers the potential for more precise, real-time assessment of disease presence, progression, and therapeutic response [13].

SUPERIORITY OF PRECISION DIAGNOSIS AND THERAPY OVER TRADITIONAL METHODS

The precision medicine paradigm offers a transformative approach to periodontal care by integrating molecular, genetic, environmental, and behavioural data to tailor prevention and treatment strategies to the individual. Unlike traditional methods, this approach allows for the development of highly targeted therapeutic regimens that align with a patient's specific genetic and biological profile, reducing the risk of adverse effects and enhancing drug efficacy.

Furthermore, precision diagnostics can stratify patients based on predicted therapeutic responsiveness, thereby improving clinical trial efficiency by identifying responders and non-responders at an early stage. This reduces the time, cost, and attrition associated with drug development. Precision approaches also enhance public health strategies by enabling early identification of at-risk individuals, thus facilitating preventive interventions, and reducing the burden of disease over time. Overall, precision periodontics represents a paradigm shift from reactive, uniform interventions to proactive, individualized healthcare delivery.

BIOMARKERS IN PRECISION PERIODONTICS

Biomarkers are quantifiable indicators that reflect physiological, pathological, or therapeutic responses within the body. They provide dynamic insight into ongoing biological activities by detecting specific molecular signatures such as proteins, nucleic acids, or metabolic by- products produced by cells or tissues in response to genetic, epigenetic, or environmental factors [14]. In the context of periodontal diagnostics, biological samples commonly used for biomarker analysis include dental plaque, saliva, and gingival crevicular fluid (GCF). The classification of biomarkers is typically informed by patient medical history, clinical examination, and diagnostic testing to determine the disease stage and activity level [15].

Predictive Biomarkers

Predictive biomarkers are instrumental in identifying individuals with an elevated risk of developing periodontal disease, enabling clinicians to tailor preventive strategies, refine screening protocols, and modify risk-related behaviours before clinical manifestation. One of the most prominent classes of predictive markers is single nucleotide polymorphisms (SNPs), which can highlight inherited susceptibility to periodontal disease [15].

Certain immunogenetic profiles have been associated with inadequate clearance of periodontal pathogens, contributing to exaggerated tissue destruction. For instance, SNPs in genes such as Interleukin-1 β (IL1β), Interleukin 1 Receptor Antagonist (IL1RA), Fc gamma receptor IIb (FcγRIIb), Vitamin D Receptor (VDR), and Toll-Like Receptor 4 (TLR4) have been implicated in heightened vulnerability to aggressive periodontitis. Conversely, polymorphisms in IL1 β, IL1RN, IL6, IL10, VDR, CD14, TLR4, and matrix metalloproteinases 1 (MMP1) are thought to contribute to the general risk of chronic periodontitis [16].

In a study conducted by Schulz et al., the relationship between IL-1 gene cluster polymorphisms and the subgingival colonization of Aggregatibacteractinomycetemcomitans was examined. While a correlation between the genetic profile and microbial colonization was observed, the findings did not conclusively establish this as an independent risk factor for periodontitis progression [17].

Prognostic Biomarkers

Prognostic biomarkers are utilized after disease onset and are typically static, providing crucial information on disease behaviour, anticipated progression, and response to therapy. Unlike predictive markers, they do not require temporal change to be clinically useful. These markers aid clinicians in selecting optimal treatment modalities, anticipating complications, and crafting individualized maintenance plans to support long-term periodontal health [18].

They are essential for determining both the stage (severity and extent) and grade (rate of progression and risk factors) of the disease parameters vital to forming an accurate prognosis and evidence-based treatment roadmap [19]. A comprehensive meta-analysis by Feng et al. demonstrated a significant association between the IL-1A (-889C/T) polymorphism and increased susceptibility to chronic periodontitis across diverse ethnic groups, including African, European, and American populations [20].

Diagnostic Biomarkers in Periodontics

Diagnostic biomarkers encompass a broad spectrum of biochemical and microbiological indicators that reflect active disease processes in periodontal tissues. These markers are particularly valuable in assessing disease activity, gauging the patient's response to therapy, and monitoring compliance with periodontal treatment regimens. Included within this group are surrogate biomarkers representing inflammatory status, soft and hard tissue metabolism, and host response mechanisms [21].

INFLAMMATORY BIOMARKERS

Inflammatory markers serve as crucial indicators of the host's immunoinflammatory response and are extensively investigated in the context of both gingivitis and periodontitis. These include proinflammatory and anti-inflammatory cytokines, which can help assess disease severity, progression, and therapeutic responsiveness.
Key cytokines from the T-helper cell (Th) subsets include:

- Th1: IL-1β, IFN-γ, TNF-α
- Th2: IL-4, IL-6, IL-10
- Th17: IL-17
- Additional: IL-8

Among these, Th1 and Th17 cytokines tend to be elevated in active periodontal disease and generally diminish following effective therapy, making them more specific markers of disease activity. In contrast, Th2 cytokines, while still important, may have comparatively lower diagnostic specificity [22–25].

An imbalance between reactive oxygen species (ROS) and antioxidant defences is another hallmark of periodontal pathology. Oxidative stress markers such as malondialdehyde, nitric oxide, total oxidant status (TOS), total antioxidant capacity (TAC), and 8-hydroxydeoxyguanosine (8-OHdG) are measurable in saliva and show sensitivity to periodontal treatment, offering insights into systemic and local oxidative burden. Salivary profiles tend to be more diagnostically reliable than those from GCF in this context.

Calprotectin, a calcium- and zinc-binding protein with immunomodulatory functions, inhibits immunoglobulin production and plays a defensive role against bacterial invasion, especially Porphyromonasgingivalis, by upregulating at inflammatory sites. Elevated levels in GCF are indicative of active periodontal inflammation [26,27]. In a comparative study, Becerik et al. evaluated calprotectin, osteocalcin, and cross-linked N-terminal telopeptide (NTx) levels in GCF across various periodontal conditions. They concluded that while elevated calprotectin reflected ongoing inflammation, fluctuations in osteocalcin and NTx levels suggested altered bone metabolism in periodontitis [28].

Soft Tissue Biomarkers

Soft tissue degradation markers, particularly MMPs, are pivotal in the breakdown of extracellular matrix components. Elevated levels of MMP-8 and MMP-9 are consistently found in periodontitis, while MMP-13 and MMP-8 are also notably elevated in peri-implantitis, indicating their potential use in peri-implant diagnostics.

Additionally, factors involved in tissue repair and angiogenesis, such as platelet-derived growth factor (PDGF) and vascular endothelial growth factor (VEGF), are found at increased levels in diseased gingival tissues. VEGF is upregulated in epithelial and endothelial cells of periodontitis-affected sites, suggesting its role as a potential biomarker for healing potential and disease activity [29].

A comprehensive meta-analysis by Ghassib et al. evaluated the utility of biomarkers in peri- implant crevicular fluid (PICF) to differentiate healthy implants from those affected by peri- implant mucositis or peri-implantitis. The findings supported the diagnostic value of IL-1β and IL-6, which can serve as reliable adjuncts to clinical evaluation when identifying peri-implant disease [30].

Bone Turnover Markers (BTMs)

Bone turnover markers provide insights into the dynamic processes of bone resorption and formation in periodontal tissues. Central to this regulation are the molecules receptor activator of nuclear factor-kappa B (RANK) and its ligand RANKL, which promote osteoclast differentiation and bone resorption. In contrast, osteoprotegerin (OPG) acts as a decoy receptor for RANKL, inhibiting bone resorption and supporting bone remodelling [31]. While these markers are closely linked with the pathophysiology of bone loss in periodontitis, their precise diagnostic utility in assessing real-time disease activity remains to be conclusively established.

Osteonectin, a glycoprotein involved in mineralization and matrix organization, has shown promise as a sensitive marker for early detection of periodontal disease, outperforming the N- terminal propeptide of type I collagen (PINP) in sensitivity.

Additionally, osteopontin (OPN), a multifunctional phosphoprotein essential in bone remodelling, has been inversely correlated with probing pocket depth, suggesting a potential regulatory role in disease modulation and wound healing [32].

Histopathological Markers
Although not routinely employed in clinical periodontology, histopathological biomarkers can offer critical insights into the cellular and molecular mechanisms underpinning disease initiation, progression, and severity. These markers may also aid in identifying new, clinically applicable biomarkers by elucidating tissue-level changes in inflammatory and degenerative periodontal conditions.

GINGIVAL CREVICULAR FLUID AS A BIOMARKER SOURCE

GCF has long been recognized for its rich content of diagnostic biomarkers, reflecting both local host response and microbial activity in periodontal pockets. Due to its proximity to the site of periodontal pathology, GCF is a particularly informative source for assessing site- specific disease activity.

GCF contains a diverse array of biomarkers, including interleukins, tumor necrosis factor-alpha (TNF-α), prostaglandin E2 (PGE2), osteocalcin, RANK, OPG, RANKL, transforming growth factor-beta1 (TGF-β1), MMPs, acid and alkaline phosphatase (ALP), aspartate aminotransferase (AST), IL-1RA, IFN-γ among others.

These molecular markers are typically classified into six functional categories: indicators of cell death, markers of tissue degradation, inflammatory mediators, regulators of bone resorption, components involved in bone formation and mineralization, and other miscellaneous biomarkers.
Studies have demonstrated strong associations between GCF levels of proteases and collagenases and clinical parameters such as pocket depth. Barros et al. emphasized the utility of GCF as a reservoir of biomarkers that distinguish active disease sites from quiescent ones.

Similarly, in an extensive review, Kaur et al. (2017) catalogued a wide array of host defence mediators in GCF, reinforcing its value in biomarker discovery for periodontitis. However, despite its diagnostic promise, GCF sampling is technique-sensitive and may pose challenges in routine chairside applications [33].

Saliva as a Biomarker Source
Saliva presents a highly practical, non-invasive medium for periodontal diagnostics. Its ease of collection, minimal processing requirements, and continuous production make it an attractive alternative to more complex biofluids. Saliva contains a diverse array of molecules, including cytokines, enzymes, DNA/RNA fragments, antibodies, hormones, and growth factors, all of which may contribute to a comprehensive assessment of periodontal and peri-implant health.

Commonly analysed salivary biomarkers in periodontitis include IL-1β, IL-6, IL-8, IL-10, IL- 12, TNF-α, MMP-3, MMP-8, MMP-9, and TIMP-1, all of which have shown elevated levels in disease states. Additionally, markers of osteoclastogenesis, such as RANK, RANKL, and OPG, and oxidative stress-related proteins like malondialdehyde, urate, ascorbate, and myeloperoxidase, are found in higher concentrations in individuals with peri-implantitis.

Despite the diagnostic potential of salivary analysis, a consensus on standardized biomarker panels for clinical application is lacking. The heterogeneity in study designs and outcome measures hinders the development of universally accepted biomarkers for personalized periodontal care. Nonetheless, MMPs and interleukins remain among the most promising salivary indicators, holding considerable potential for future diagnostic platforms in periodontology [34].

Strategies for Implementing Precision in Periodontics
The integration of cutting-edge technologies into periodontics is paving the way for a shift toward precision-based diagnosis and treatment. Although

still in the nascent stages, precision periodontics leverages multi-omics platforms, digital tools, and advanced analytics to tailor care to individual patient profiles.

The selection of biomarkers is highly dependent on the diagnostic objective. For instance:

- Microbiological profiling benefits from metagenomics, meta-transcriptomics, and culturomics to characterize the subgingival microbial environment.
- Proteomic analyses are crucial for quantifying cytokines and other protein mediators involved in the inflammatory response.
- Transcriptomics and metabolomics may be employed for a deeper understanding of host-pathogen interactions and metabolic changes.

Despite their promise, biomarker analyses face challenges including false positives, false negatives, and variability in results. These issues necessitate the use of high-fidelity equipment and skilled personnel to ensure reproducibility and clinical relevance.

Precision Dentistry and the Role of Advanced Technology

Precision dentistry has significantly enhanced diagnostic accuracy and therapeutic outcomes through the adoption of digital and automated systems. Modern clinics are increasingly incorporating real-time vital sign monitoring, digital charting, and equipment diagnostics into routine care.

- Radio-Frequency Identification (RFID) is used to track instruments and streamline clinical workflows.
- Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) has revolutionized prosthodontics by replacing traditional impression techniques with precise digital workflows.
- 3D scanning technologies have eliminated the discomfort associated with conventional dental impressions, improving the patient experience.
- Operating microscopes now support enhanced visualization during delicate procedures such as endodontic therapy and periodontal microsurgery, leading to better clinical precision and outcomes [35].

ARTIFICIAL INTELLIGENCE (AI) IN PRECISION PERIODONTICS

Artificial intelligence is increasingly synergizing with precision dentistry to enhance patient care. AI algorithms are adept at processing and interpreting large, complex datasets, aligning well with the personalized nature of precision medicine.

Key contributions of AI in this domain include:

- Improved diagnostic accuracy through pattern recognition and predictive modelling.
- Personalized treatment planning based on integrated data analysis.
- Predictive maintenance of dental equipment to reduce downtime.
- Patient engagement tools such as AI-powered virtual assistants to enhance adherence and education.
- Accelerated research and development, fostering the discovery of novel therapeutic agents and interventions.

Despite these advantages, AI integration must address challenges such as data privacy, regulatory compliance, education and training of clinicians, and cost-effectiveness to be fully realized in clinical settings [36].

Barriers to the Implementation of Precision Periodontics

Fig 1- Barriers to the Implementation of Precision Periodontics

A range of systemic, technological, and educational barriers must be addressed to facilitate the successful implementation of precision periodontics (illustrated in Figure 1).[37]

- **Data Integration-** The heterogeneity of data from genomic, clinical, and behavioural sources complicates integration. This challenge can be mitigated by adopting electronic health records (EHRs), common data models, and interoperable precision medicine platforms.
- **Multifactorial Etiology-** Periodontitis involves complex host-microbe interactions and systemic influences, complicating biomarker discovery. Collaborative research and the application of machine learning algorithms may help untangle these complexities.
- **Limited Microbiome Understanding-** The structure and function of the periodontal microbiome remain incompletely characterized, limiting the efficacy of targeted antimicrobial therapies. Techniques such as 16S rRNA gene sequencing and next- generation antimicrobials offer potential breakthroughs.
- **Awareness and Education Gaps-** Many dental practitioners are unfamiliar with advanced diagnostics and personalized care approaches. Implementation can be enhanced through continuing education programs, hands-on workshops, and online learning platforms.
- **Regulatory Challenges-** Rapid innovation often outpaces existing regulatory frameworks. Engagement with regulatory bodies is essential to establish clear guidelines, validation protocols, and standardized metrics.
- **Patient-Cantered Barriers-** Socioeconomic disparities, cultural attitudes, and behavioural compliance significantly impact treatment success. Emphasis on individualized care plans, cultural competence, and patient empowerment strategies is crucial [38].
- Precision periodontics represents a paradigm shift in the diagnosis and management of periodontal diseases by moving away from generalized approaches toward individualized care. This evolution is being driven by advances in biomarker research, digital dentistry, and artificial intelligence. However, the successful clinical integration of precision strategies hinges on the rigorous validation of biomarkers and the development of reliable, standardized diagnostic platforms.
- Future research must prioritize the design and implementation of practical biomarker evaluation protocols, with a strong emphasis on point-of-care testing (POCT). Despite the wealth of molecular insights gained through recent scientific efforts, the lack of validated periodontal biomarkers for routine diagnostic use remains a critical bottleneck. As the field advances, it becomes imperative to identify and clinically validate the most specific and patient-relevant biomarkers, enabling the transition from research to personalized clinical application.
- Realizing the full potential of precision periodontics will require interdisciplinary collaboration, regulatory alignment, continuous professional education, and patient engagement. With these efforts, precision periodontics can progress from an emerging concept to a transformative clinical reality in periodontal healthcare.

CONCLUSION-

The emergence of precision periodontics holds significant potential to transform periodontal diagnosis and treatment by enabling highly individualized care. Achieving this goal requires strict adherence to standardized protocols for biomarker validation to ensure their integration into evidence-based clinical workflows. Current research should prioritize the development of clinically applicable biomarker assessment frameworks, particularly focusing on point-of-care testing (POCT), which remains at an early stage in the field of periodontology. Progress in this area is hindered by the lack of fully validated biomarkers for diagnostic use, limiting the practical application of biomarker-based analysis in precision diagnostics. Therefore, there is a critical need to identify and evaluate the most disease-specific and patient-relevant biomarkers to advance the implementation of precision periodontics into routine clinical practice.

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Review Article

Smear Layer in Conservative Dentistry and Endodontics: A Comprehensive Review

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Abstract:
The smear layer is a thin, amorphous deposit produced during various dental procedures such as cavity preparation and root canal instrumentation. Comprising organic and inorganic debris including dentin particles, collagen, remnants of pulp tissue, bacteria, and saliva, its role in clinical dentistry is widely debated. While it can act as a barrier against bacterial penetration and reduce dentinal hypersensitivity, it can also obstruct adhesion, inhibit irrigant penetration, and harbour microorganisms. This review provides an in-depth exploration of the smear layer covering its history, structure, formation mechanisms, and implications in conservative dentistry and endodontics. Emphasis is placed on contemporary removal strategies and the impact of smear layer management on clinical success. The goal is to inform evidence-based practice by presenting balanced insights into the pros and cons of smear layer preservation or removal.

Keywords: smear layer, endodontics, conservative dentistry, EDTA, bonding, irrigants, dentin permeability

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INTRODUCTION

The smear layer is a micro-deposit created when dental hard tissues are mechanically altered, typically during restorative and endodontic procedures. First identified by McComb and Smith in 1975, it consists of a complex mix of organic and inorganic materials that adhere to cavity or root canal walls. Its presence significantly influences dentin permeability, bonding strength, and the effectiveness of irrigation and disinfection protocols. Clinicians must understand the smear layer's characteristics to make informed decisions regarding its preservation or removal.

HISTORICAL BACKGROUND

Initial insights into tooth surface alterations from instrumentation emerged in the 1950s. Studies by Lammie and Draycot (1952) and Peyton and Mortell

(1956) highlighted surface irregularities using early microscopy techniques. The term "smear layer" was conceptualized following detailed SEM work by Boyde et al. in the 1960s, who attributed its formation to frictional heat and mechanical shearing. These findings sparked decades of research into its clinical significance.

DEFINITIONS

The smear layer has been described in various ways, reflecting its complex composition and multifaceted clinical effects:

As a thin film of debris that occludes dentinal tubules.

As a barrier to adhesive penetration.

As a contaminant interfering with chemical bonding.

As a protective film that limits dentin permeability. These definitions underscore the dual nature of the smear layer—as both a potential ally and adversary in dental treatment.

STRUCTURE AND FORMATION

Comprising particles of enamel, dentin, and other debris, the smear layer varies from 1 to 5 µm in thickness and may extend into dentinal tubules by up to 40 µm. Its formation is influenced by the instrument type, use of coolant, cutting force, and whether the dentin is wet or dry during preparation. SEM imaging reveals a granular and amorphous morphology, often consisting of agglomerated particles that resist dissolution by water or weak acids.

SMEAR LAYER IN CONSERVATIVE DENTISTRY

In operative dentistry, the smear layer plays a significant role in modifying dentin permeability, affecting both fluid movement and adhesive bonding. While its presence can reduce post-operative sensitivity by sealing tubules, it may also impede adhesive monomer infiltration, leading to weak bonds and microleakage. The decision to retain or remove the smear layer often depends on the adhesive system used. Total-etch systems typically require its removal, while self-etching systems may incorporate it into the bonding substrate.

SMEAR LAYER IN ENDODONTICS

In endodontics, the smear layer is generated along the canal walls during biomechanical preparation. It may contain microbial elements and necrotic tissue, acting as a barrier to irrigants and medicaments. While its retention may minimize dentin permeability and prevent reinfection, most endodontists advocate its removal to enhance the penetration of sealers and irrigants, and to reduce apical leakage. Smear layer removal has been linked to better obturation and reduced risk of treatment failure.

REMOVAL TECHNIQUES AND AGENTS

A wide range of chemical agents and activation techniques are employed to remove the smear layer:

- EDTA (17%): Chelates calcium ions and effectively removes the inorganic portion.
- Sodium Hypochlorite (NaOCl, 3–5.25%): Dissolves organic matter but is ineffective against the smear layer alone.
- Citric, Maleic, and Etidronic Acids: Used alone or in combination, especially effective in the apical third.

Activation techniques include ultrasonic agitation, diode laser, sonic activation (e.g., Eddy), and negative pressure systems (e.g., EndoVac). Combination protocols—e.g., NaOCl + EDTA or NaOCl + etidronate—have shown higher efficacy, especially when paired with agitation techniques.

BONDING AND THE SMEAR LAYER

Adhesion to dentin is critically influenced by the smear layer. In systems requiring removal (etch-and-rinse), phosphoric or citric acid is used to expose collagen networks and open tubules, allowing resin infiltration. However, over-etching increases sensitivity. Self-etch adhesives partially dissolve the smear layer and incorporate it into the hybrid layer. Resin-based sealers and bonding agents must be matched to smear layer conditions for optimal performance.

CLINICAL IMPLICATIONS AND CONTROVERSIES

The debate over smear layer management is grounded in balancing clinical benefits and drawbacks:

- **Advantages of Retention**: Reduces dentin permeability and sensitivity; acts as a barrier to microbial invasion.
- **Advantages of Removal:** Enhances bonding, improves irrigant and medicament penetration, increases sealing ability.

Restorative dentistry often supports selective modification, while endodontics leans strongly toward complete removal. Ultimately, clinician preference, procedural goals, and material compatibility guide management decisions.

CONCLUSION

The smear layer continues to be a focal point of research and clinical consideration in modern dentistry. Its multifaceted impact on adhesion, permeability, disinfection, and sensitivity necessitates tailored approaches to each clinical scenario. Through a comprehensive understanding of its behavior and implications, dental professionals can make informed decisions that optimize patient outcomes across both restorative and endodontic procedures.

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